# ANNUAL REPORT

OF THE

# COMMISSIONERS OF INLAND FISHERIES

# 1900.

State of Rhode Island and Providence Plantations.

# THIRTY-FIRST ANNUAL REPORT

OF THE

*Compliments of*

***Commissioners of Inland Fisheries,***

*Providence, R. I.*

PROVIDENCE:
E. L. FREEMAN & SONS, STATE PRINTERS.
1901.

State of Rhode Island and Providence Plantations.

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OF THE

# COMMISSIONERS OF INLAND FISHERIES,

MADE TO THE

# GENERAL ASSEMBLY

AT ITS

# JANUARY SESSION, 1901.

A PROVIDENCE:
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1901.

## COMMISSIONERS OF INLAND FISHERIES OF RHODE ISLAND.

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| J. M. K. SOUTHWICK, *President* | Newport, R. I. |
| HENRY T. ROOT, *Treasurer* | Providence, R. I. |
| WM. P. MORTON, *Secretary* | P. O. Box 966, Providence, R. I. |
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| HERMON C. BUMPUS, Ph. D. | Brown University. |
| WM. H. BOARDMAN | Central Falls, R. I. |

# REPORT.

*To the Honorable the General Assembly of the State of Rhode Island and Providence Plantations, at its January Session, 1901:*

The Commissioners of Inland Fisheries herewith present their annual report for the year 1900:

The work undertaken by the commissioners during the past year may be tabulated as follows:

*First.* The stocking of our ponds and streams with suitable fresh-water fish, through the distribution of eggs and fry.

*Second.* The collection of definite data respecting the times of arrival and departure of various food-fishes, and the preparation of statistics of exportation.

*Third.* A continuation of the observations on the breeding periods of native marine animals.

*Fourth.* The location of fish-traps within the waters of Narragansett Bay, and the collection of statistical data bearing upon their ownership.

*Fifth.* Observations to show the influence that trap-fishing may have upon line-fishing.

*Sixth.* The continued examination of the physical and biological conditions of the waters of the Bay, begun in 1898.

*Seventh.* A preliminary survey of the shores of the bay, for the purpose of determining those portions which are most productive of young seed-clams.

*Eighth.* A continued investigation of the life-history of the clam. Methods of artificial propagation and cultivation.

*Ninth.* Continued work on off-shore fisheries.

*Tenth.* An investigation of the habits and growth of the scallop.

*Eleventh.* Further observations on the red water plague, with notes on its occurrence elsewhere.

*Twelfth.* Additions to the list of fishes known to inhabit the Bay, with remarks on rare fishes recently caught.

*Thirteenth.* Experiments in lobster culture.

The scientific work which your commission was able to accomplish was made possible by the special appropriation of last year, which provided for the construction of a new floating laboratory and for the purchase of a small naphtha launch.

The new floating laboratory was towed to Wickford on May 17, and placed at the same moorings which held the old house-boat of the previous year. It was built by the Providence Dry Dock Co., and is a thoroughly staunch craft which should be serviceable for many years. A brief description is as follows: Two pontoons, 52 feet long, 4 feet wide, and 4 feet deep, of three-inch hard pine, completely decked with two-inch hard pine, each pontoon with three bulk-heads and four water-tight compartments accessible by hatches, painted all over, copper paint below. Pontoons placed 8 feet apart and securely fastened by cross-beams and knees at each end. A house 10 x 10 feet at each end of the boat, with floors of two-inch hard pine, roof, sides, doors, shelves, and closets of North Carolina pine, painted outside and natural wood inside. Roof 7 feet from floor, covered with canvas, and painted. The well between the pontoons is open from one house to the other for a distance of 20 feet, and under the houses is accessible through hatches in the floors. The laboratory equipment was transferred from the old house-boat and additional apparatus added. In December the craft was laid on shore and carefully blocked up beyond the reach of the tide.

The experience of your commission in the past three years has proved in the most convincing manner the value of a house-boat as a laboratory for investigation of problems connected with ma-

rine biology, and this particular structure, the first of its kind yet built, is eminently satisfactory. It has been the object of no little interest in outside quarters, and a description of it was sent by request to the Fisheries Commission in New Zealand.

The old house-boat, which did good service during the previous season, was laid up on the beach and will not float again. It has been in commission throughout the summer as an accessory laboratory and quarters for two assistants and has served as a storehouse during the winter.

The naphtha launch "Athleen," 26½ feet long, fitted with a 4-horse-power Murray and Tregartha engine, was purchased in Boston, and was launched at Wickford June 27. It is an excellent boat and has been of great practical service in locating fish-traps, in collecting clams and scallops, in exploring the shore in various parts of the bay, and in light dredging. A small, well-built tender was bought with the launch and is so light that it can easily be taken on board.

The small lobster hatchery which served as a house-boat on the Kickemuit river in 1898 and 1899 was not in commission during the past season. It may be possible to use it during the coming season however, now that the launch provides means of communication with the headquarters at Wickford.

Your commission recalls with pleasure the reception its investigations have met with outside the State. For two years the commission has been in correspondence with the Imperial Fisheries Bureau of Japan in regard to all these researches. The paper on the "Peridinium and Red Water in Narragansett Bay" has been translated into Japanese, at the request of Mr. K. Nishikawa of that bureau. The special interest of the Japanese in "Peridinium" was due to the fact that a smilar phenomenon of "red water" occurred in Japanese waters, caused by an organism thought at first to be indentical with our form, but later found to belong to a related genus. The two papers on the "Natural History of the Star-Fish" have been reprinted in the Bulletin of the U. S. F. C., by request of that commission.

More interest has been shown in the investigations on the clam than in those already mentioned, from the fact that they have served as a basis for enterprises in clam-culture. Several individuals and companies have begun rearing clams on a large scale since the paper was published, and an active correspondence with the parties has been carried on. These enterprises have been started in other States—Massachusetts, Connecticut, and New York, as well as in California.

Inquiries into the natural history of the quahog and information regarding the possibility of its artificial propagation, breeding, etc., have been received, but cannot be answered at present.

It is hoped on the part of your commission that the results of the past season's work on the clam, scallop, and lobster will be received with the same interest and will encourage further efforts toward a cultivation of these animals and toward increasing the natural supply.

At the request of the committee having in charge the Rhode Island exhibit for the Pan-American Exposition at Buffalo, your commission has loaned for exhibition in the Rhode Island department a series of cases, illustrating the natural history of the clam, scallop, lobster, and star-fish, together with a large relief map of Narragansett Bay showing the contour of the bay and depth of water at various places and the location of the fish-traps, oyster-beds, and scallop-grounds. The committee in charge of the State exhibit offered to bear the expense connected with the installation of the cases, etc.

The receipts and disbursements of the commission have been as follows:

*State of Rhode Island in Account with Commissioners of Inland Fisheries.*

| | | |
|---|---|---|
| 1899. | Dr. | |
| Dec. 31. | To balance due commissioners | $441 57 |
| 1900. | | |
| Sept. 18. | To paid for 40,000 yearling trout and distributing same. | 1,142 44 |

| 1900. | Dr. | |
|---|---|---|
| Dec. 31. | To paid for investigating lobsters, clams, flat-fish, and star-fish | $1,125 34 |
| | To paid for expenses of Commissioners | 280 79 |
| | To paid for printing, postage, etc | 32 80 |
| | To paid for new house-boat and naphtha launch | 1,550 00 |
| | Total | $4,572 94 |

| 1900. | Cr. | |
|---|---|---|
| Feb. 1. | By cash from State Treasurer | $107 95 |
| | " " " | 277 56 |
| Mar. 22. | " " " | 22 62 |
| Apr. 30. | " " " | 46 17 |
| May 10. | " " " | 9 00 |
| | " " " | 51 64 |
| 22. | " " " | 1,000 00 |
| | " " " | 22 52 |
| June 12. | " " " | 75 61 |
| | " " " | 550 00 |
| July 24. | " " " | 173 12 |
| Aug. 8. | " " " | 22 00 |
| 17. | " " " | 9 50 |
| | " " " | 20 00 |
| | " " " | 112 81 |
| | " " " | 16 26 |
| 24. | " " " | 41 75 |
| Sept. 18. | " " " | 1,000 00 |
| 28. | " " " | 50 00 |
| Nov. 1. | " " " | 17 00 |
| 5. | " " " | 450 00 |
| | " " " | 50 00 |
| 12. | " " " | 9 20 |
| Dec. 18. | " " " | 100 00 |
| | " " " | 45 85 |
| | " " " | 75 00 |
| | " " " | 30 00 |
| | " " " | 30 60 |
| | " " " | 5 10 |

| 1900. | Cr. | |
|---|---|---|
| Dec. 18. | By cash from State Treasurer | $66 99 |
| 31. | By balance due commissioners | 84 69 |
| | Total | $4,572 94 |

J. M. K. SOUTHWICK,
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HERMON C. BUMPUS,
WM. H. BOARDMAN.

*Commissioners of Inland Fisheries.*

## 1. The Stocking of our Ponds and Streams with Suitable Fresh-Water Fish, Through the Distribution of Eggs and Fry.

### *Brook Trout.*

The commission have purchased the past year 40,000 yearling trout which have been thoroughly distributed in the waters of the State, with the assistance of anglers, as heretofore. The past season has been an unusually dry one, and we have heard of cases where the streams have become so low that the trout have died in considerable numbers. During the open season numerous good catches have been reported to us.

### *Large-mouthed Black Bass.*

Continued success seems to have attended the introduction of this species into the waters of the State, notably in Washington County. The Penicatuck river from Mantic dam to tide-water can now be said to be fairly well stocked with fish running up to

two pounds in weight, and there is no reason to doubt that this river will soon become an ample producer of this excellent food-fish.

A number of small ponds also have been stocked during the past five years, all of which have shown gratifying results, both in increase of fish and rapidity of growth.

Through the courtesy of the U. S. Fish Commission, 1,000 fry have been received the present season, 400 of which were placed in Pawcatuck river and 700 in Richmond pond at Wood River Junction. It is the intention of the commission to reserve the above named pond for the propagation of large-mouthed black bass only, from which other waters may hereafter be stocked.

### *Small-mouthed Black Bass.*

This species is seemingly holding its own in nearly all sections.

The commission can make but little progress in the way of stocking, inasmuch as the U. S. Fish Commission is not at present propagating the small-mouthed black blass. The only available method at present is to take adult fish by hook and line and to transplant them alive to other waters. This method has been adopted wherever practicable, and has been attended with good results.

### *Land-locked Salmon.*

There seems to be no body of water in Rhode Island that is peculiarly adopted to the culture of the fresh-water salmon. Great depth, low temperature of water, and a suitable inlet of pure water for spawning are necessary natural conditions for successful propagation. However, inasmuch as the experience of the State has been very slight, the commissioners have made some efforts in the way of experiments.

A quantity of eggs were received from the U. S. Fish Commission. These were hatched and reared until the fry were four months old, when they were distributed as follows:

| | |
|---|---|
| 1,000 | Watchaug Pond. |
| 2,000 | Sneech Pond. |
| 4,000 | Wallum Pond. |

### *White Perch.*

Through the courtesy of the commissioner and superintendent of parks, we were enabled to secure 100 white perch. These were placed in Moswansicut pond.

### *Shad.*

We obtained from the U. S. Fish Commission 1,000,000 shad fry, which were planted as follows: 500,000 in Point Judith ponds, 150,000 in Runnins River, and 350,000 in Palmer's River at the shad factory.

## II. The Collection of Definite Data Respecting the Times of Arrival and Departure of Various Food-Fishes, and the Statistics of Exportation.

The difficulty hitherto experienced by the commission in systematically collecting data concerning the arrival and departure of fishes is partly removed by the purchase of the small launch. It is hoped that more can be accomplished in this direction next year.

*The following table gives the amount of the monthly exports of fish, lobsters, and sword-fish for the year 1900 from Newport, R. I.*

| | Fish. | Lobsters. | Sword-fish. |
|---|---|---|---|
| January | 778 barrels. | 613 barrels. | ...... |
| February | 435 " | 602 " | ...... |
| March | 153 " | 490 " | ...... |
| April | 357 " | 481 " | ...... |
| May | 15,899 " | 309 " | ...... |
| June | 9,879 " | 506 " | 101 barrels. |
| July | 2,211 " | 698 " | 65 " |
| August | 3,337 " | 592 " | ...... |

| | Fish. | Lobsters. | Sword-fish. |
|---|---|---|---|
| September............ | 2,099 barrels. | 263 barrels. | ...... |
| October............... | 1,417 " | 117 " | ...... |
| November.............. | 1,009 " | 94 " | ...... |
| December.............. | 610 " | 28 " | ...... |
| Totals............ | 38,184 barrels. | 4,793 barrels. | 166 barrels. |

*Table showing the shipments of fish, lobsters, and sword-fish by the principal transportation lines from Newport during the last ten years.*

| | Fish. | Lobsters. | Sword-fish. |
|---|---|---|---|
| 1891.................... | 18,032 barrels. | 2,204 barrels. | Not reported. |
| 1892.................... | 26,832 " | 2,123 " | " |
| 1893.................... | 24,452 " | 1,399 " | " |
| 1894.................... | 17,861 " | 2,392 " | " |
| 1895.................... | 24,622 " | 2,119 " | " |
| 1896.................... | 33,064 " | 2,115 " | 143 barrels. |
| 1897.................... | 25,098 " | 2,039 " | 45 " |
| 1898.................... | 34,065 " | 1,163 " | 74 " |
| 1899.................... | 34,917 " | 4,143 " | 162 " |
| 1900.................... | 38,184 " | 4,793 " | 166 " |
| Totals............ | 277,087 barrels. | 24,490 barrels. | 590 barrels. |

## III. A Continuation of the Observations on the Breeding of Native Marine Animals.

Facts concerning the breeding of various marine animals are being collected and filed for future publication.

## IV. The Location of Fish-traps within the Waters of Narragansett Bay, and the Collection of Statistical Data Bearing upon Their Ownership.

With the publication of the report for 1898, the State first came into possession of definite data respecting the location and ownership of fish-traps. Assisted by the boats of the U. S. Fish Commission, your commission has again visited all the fish-traps, lo-

cated them upon its chart, and determined their ownership. The report for 1899 contained a revision of these data for that year, and during the past season the traps have again been located and have all been visited in the launch with the exception of those in Sakonnet river and those off shore. We would repeat that the equipment and maintenance of these appliances represent the investment of considerable capital and the employment of a large number of men. A large proportion of the fish captured are consumed beyond the limits of the State, and the list of cities to which shipments are directly made indicates very clearly the reputation which the State must enjoy as a fisheries centre. It is unnecessary to argue that large sums of money are brought into the State through the activities of those immediately interested in this industry. A list of the principal owners of fish-traps is here given, together with the localities at which the traps are set.

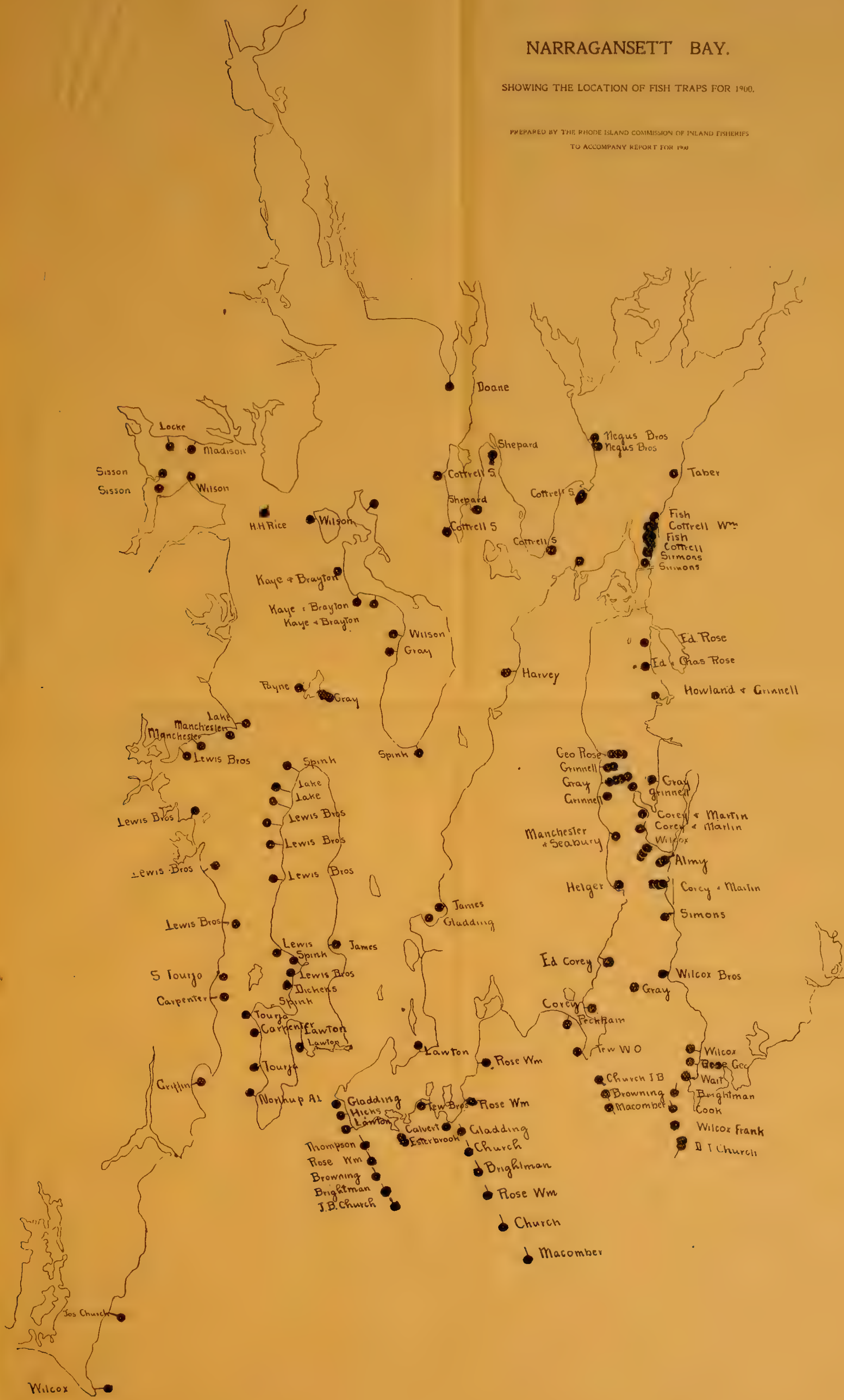
| | |
|---|---|
| Almy, Frank K. (00)* | Sakonnet River. |
| Brightman, Wm. J | Sakonnet Point. |
| Carpenter Bros | Saunderstown. |
| Carpenter, Geo | Beaver Head. |
| Church, Jos | Narragansett Pier. |
| Calvert, Geo | Coggeshall's Ledge. |
| Cook, C | Sakonnet Point. |
| Corey, Ed. (00) | Sakonnet River. |
| Corey, Ed | Sakonnet River. |
| Corey, George and Martin (000) | Sakonnet River. |
| Corey, George and Martin | Sakonnet River. |
| Corey, George and Martin | Sakonnet River. |
| Cottrell, S | Popasquash. |
| Cottrell, S | Popasquash. |
| Cottrell, S | Bristol. |
| Cottrell, S | Mt. Hope. |
| Cottrell, Wm | Tiverton. |
| Cottrell, Wm | Tiverton. |

* The signs (00) and (000) indicate double and triple traps.

# NARRAGANSETT BAY.

SHOWING THE LOCATION OF FISH TRAPS FOR 1900.

PREPARED BY THE RHODE ISLAND COMMISSION OF INLAND FISHERIES
TO ACCOMPANY REPORT FOR 1900



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| | |
|---|---|
| Dickens, ——— | Conanicut. |
| Doane, S. P | Rumstick. |
| Easterbrooks, Comer (00) | Price's Neck. |
| Fish, Clinton | Tiverton. |
| Fish, Clinton (00) | Tiverton. |
| Gladding, A. B | Brenton's Point. |
| Gladding, A. B | Coddington Cove. |
| Gray, George E | Sakonnet River. |
| Gray, George E. (0000) | Sakonnet River. |
| Gray, George E | Sakonnet Point. |
| Gray, George E | Hope. |
| Gray, George E | Prudence. |
| Griffin, ——— | Watson's Pier. |
| Grinnell, Philip (00) | Sakonnet River. |
| Grinnell, Philip (00) | Sakonnet River. |
| Grinnell, Philip | Sakonnet River. |
| Harvey, Charles | West Shore. |
| Helger, Henry (00) | Sakonnet River. |
| Hicks, O. G | Brenton's Point. |
| Howland and Grinnell | Sakonnet River. |
| James, Arnold | Coddington's Cove. |
| James, ——— | Conanicut, Potter's Cove. |
| Kaye and Brayton | Prudence. |
| Kaye and Brayton | Prudence. |
| Kaye and Brayton | Prudence. |
| Lake, Isaac | Conanicut. |
| Lake, Isaac | Conanicut. |
| Lake, Isaac | Quonset Point. |
| Lawton, Ed. | Mackerel Cove. |
| Lawton, Wm | Mackerel Cove. |
| Lawton, Ed | Brenton's Point. |
| Lawton, Ed | Brenton's Cove. |
| Lewis Bros. | Plum Beach. |
| Lewis Bros | Plum Beach. |
| Lewis Bros.. | Wild Goose Point. |

Lewis Bros. . . . Sauga Point.
Lewis Bros. . . . Conanicut.
Lewis Bros. . . . Conanicut.
Lewis Bros. . . . Conanicut.
Lewis Bros. . . . Conanicut.
Lewis Bros. . . . Conanicut.
Locke, Moses. . . . Apponaug.
Madison, Peter. . . . Apponaug.
Manchester, Daniel . . . . Vials Creek.
Manchester, Daniel. . . . Quonset Point.
Manchester and Seabury. . . . Sakonnet River.
Negus Bros. . . . Mount Hope.
Negus Bros . . . . Mount Hope.
Northrup, Al. . . . Beaver Tail.
Payne, ——. . . . Hope.
Peckham, ——. . . . Sachuest Cove.
Rice, Herbert H. . . . Warwick.
Rose, Wm. . . . Conrad's Cove.
Rose, Wm. . . . Coggeshall's Ledge.
Rose, Geo. (000). . . . Sakonnet River.
Rose, Geo. . . . Sakonnet Point.
Rose, Ed. . . . Sakonnet River.
Rose, Ed. and Chas. (00). . . . Sakonnet River.
Shepard, ——. . . . Popasquash.
Shepard, J. . . . Popasquash.
Simons, Wm. . . . Sakonnet River.
Spink, J. W. . . . Beaver Head.
Spink, J. W. . . . Conanicut.
Spink, J. W. . . . Conanicut.
Spink, J. W. . . . Prudence.
Sirmons, John M. . . . Tiverton.
Sirmons, John M. . . . Tiverton.
Sisson, ——. . . . Chippanogsett.
Sisson, ——. . . . Chippanogsett.
Taber, ——. . . . Tiverton.

Tew, Eugene and Geo . . . . . . . . . . . . Cherry Neck.
Tew, Walter . . . . . . . . . . . . Sachuest Point.
Tourjee, P . . . . . . . . . . . . Beaver Tail.
Tourjee, P . . . . . . . . . . . . Beaver Head.
Tourjee, Steven . . . . . . . . . . . . Saunderstown.
Wait, Ben . . . . . . . . . . . . Sakonnet Point.
Wilcox, Frank . . . . . . . . . . . . Sakonnet Point.
Wilcox Bros. . . . . . . . . . . . . Sakonnet River.
Wilcox Bros. (000) . . . . . . . . . . . . Sakonnet River.
Wilcox, ——— . . . . . . . . . . . . Point Judith.
Wilson, Al . . . . . . . . . . . . Potowomut Rocks.
Wilson, Al . . . . . . . . . . . . Prudence.
Wilson, Al . . . . . . . . . . . . Patience.

## Sea-Traps.

Brightman, W. J . . . . . . . . . . . . Off Seal Rock.
Brightman, W. J . . . . . . . . . . . . Off Coggeshall's Ledge.
Browning, J . . . . . . . . . . . . Off Seal Rock.
Browning, J . . . . . . . . . . . . S. Cormorant Rock.
Church, D. T. (00) . . . . . . . . . . . . Off Sakonnet Point.
Church, J. B . . . . . . . . . . . . Off Seal Rock.
Church, J. B . . . . . . . . . . . . Off Coggeshall's Ledge.
Church, J. B . . . . . . . . . . . . S. Cormorant Rock.
Church, ——— . . . . . . . . . . . . Off Coggeshall's Ledge.
Gladding, A. B . . . . . . . . . . . . Off Coggeshall's Ledge.
Macomber, Frank . . . . . . . . . . . . Off Cormorant Rock.
Macomber, ——— . . . . . . . . . . . . Off Coggeshall's Ledge.
Rose, Wm . . . . . . . . . . . . Off Coggeshall's Ledge.
Rose, Wm. R . . . . . . . . . . . . Off Seal Rock.
Thompson, Noah . . . . . . . . . . . . Off Seal Rock.
Wilcox, Frank . . . . . . . . . . . . Off Sakonnet.

## V. Observations to Show the Influence that Trap-Fishing May Have Upon Line-Fishing.

The problem involved in this question, and its local bearing, is briefly stated in the following quotation from the report of last year, as follows:

"The influence that the trap-fishing in the lower portion of the Bay may have upon the abundance of food-fish in the upper portion of the Bay has been an oft-disputed question. The heat of argument at any time has been in inverse ratio to the number of fish visiting our shores. The general question of the inexhaustibility of sea products has received special attention during the past year. W. C. McIntosh, director of the Scottish Marine Laboratory at St. Andrews, and for several years member of the Fishery Board, has endeavored to show, in his book 'The Resources of the Sea,' that there is little danger of over-fishing, that restrictive legislation is unnecessary, and that Nature is amply able to maintain an abundant supply, no matter what demands may be made upon her. Views so entirely at variance with the convictions of those who have made fishing a profession, so radically different from the opinions of those who occupy positions that have enabled them to study the abundance of various commercial fishes from year to year, and views that deliberately set at nought the legislative provisions of the various maritime countries, have naturally been seriously questioned, and the discussions have certainly brought many facts to the surface that otherwise would have remained unknown.

"So far as our own interests are concerned, there seems to be little question that certain of our native fishes have been sadly reduced in numbers through neglect and excessive fishing, but the abundance of many forms which annually come in from the open ocean, and visit our shores for the purpose of breeding, appears to remain unaffected."

The effect of extensive fishing upon the actual abundance of these migratory species is a question of international as well as national and local interest. It is a problem of great difficulty and complexity, and its satisfactory solution will doubtless be deferred for many years.

The following notes are of interest, particularly in their bearing upon the local problem, and they seem to indicate that there is no immediate danger, by means of the nearly 150 traps in the waters

of the State, of exterminating or reducing the annual catch of certain species of food fish.

### *Tautog.*

The tautog are still abundant in our bay although they have become relatively scarce in the vicinity of Woods Hole. At Pawtuxet the first specimen was taken on April 26. They were reported very abundant and large at Bristol, where Mr. Shepard caught in his trap a specimen weighing 13 pounds. They were also plentiful in the lower Bay. Capt. Isaac L. Church, of Newport, has kindly furnished the Commission with the following data concerning his catch from June 11 to October 16, 1900.

*Account of Tautog Caught by Capt. Church during the Year 1900, together with Prices Obtained for the Same :*

| | | | | | |
|---|---|---|---|---|---|
| June 11 | 1,031 | pounds at | 3 | cents | $30 93 |
| 22 | 667 | " | 4 | " | 26 68 |
| 27 | 565 | " | 3 | " | 16 95 |
| July 5 | 560 | " | 3 | " | 16 80 |
| 17 | 762 | " | 3 | " | 22 86 |
| 25 | 818 | " | 3 | " | 24 56 |
| Aug. 3 | 531 | " | 3 | " | 15 93 |
| 13 | 500 | " | 5 | " | 25 00 |
| 31 | 743 | " | 5 | " | 37 15 |
| | 558 | " | 5 | " | 27 90 |
| Sept. 22 | 1,074 | " | 3 | " | 32 22 |
| 28 | 934 | " | 3 | " | 28 02 |
| Oct. 8 | 819 | " | 3 | " | 24 57 |
| 16 | 695 | " | 3 | " | 20 85 |
| | 268 | " | 3 | " | 8 04 |
| Total | 10,525 | Avg. price. | $3\frac{4}{10}$ | " | $358 44 |

Capt. Church fishes as a pastime, and his observation that the tautog are as plentiful as they were when he was a boy, in 1860, is of particular interest in showing that there is no apparent de-

crease in quantity, although his catches in the last eight years were all slightly better than during this season.

### *Squiteague.*

These have been abundant. They were taken in the upper waters of the Bay from June to the middle of November. In former years Buzzard's Bay and vicinity were spawning grounds of the squiteague, but now the young can be obtained only in the Wareham and Acushnet rivers, and there only in very small numbers. Judging from the abundance of the young in Narragansett Bay it would seem that Rhode Island waters were favorite spawning grounds at present.

### *Scup.*

The catch of scup has been good, but not extraordinary. The first were taken in Noah Thompson's trap, off Newport, April 21. The temperature of the water was a little below the average, but the first specimens appeared at the usual time.

### *Hickory Shad.*

These fish have been here in considerable numbers.

### *Blue-Fish.*

This year's catch has been relatively small.

### *Menhaden.*

The menhaden season has been the most successful in three years according to the Fisheries Company. The total catch for 1900 is 894,359 barrels which is 421 barrels more than that of 1889. During the latter part of August the menhaden were very scarce in the bay. Fishermen had to pay as high as six cents apiece for them as bait. The U. S. F. C. Schooner "Grampus" was prevented from making a second trip for tile-fish because of the scarcity of bait.

### *Alewives.*

Mr. Geo. A. Griffin, of Wakefield, R. I., in response to the inquiries of the commission, says that 3,128 barrels were exported and sold in the New York markets at the rate of $4.50 per barrel, while about 35,000 fish were sold to the local trade for a net price of $500.

### *Flat-Fish—Winter Flounder.*

The past season was unusually productive of flat-fish. During the early part of April, Lewis Brothers, of Wickford, caught 1,200 in a trap which had been set only one day. It is an extremely interesting fact that the dark bellied variety, which gradually came into notice several years ago, and attained the maximum of its abundance about three years ago, is now on the decline. Last season, according to a trustworthy estimate, only about 4 per cent. were colored on the under surface, while three years ago at least 33 per cent. were so colored.

### *Cod.*

The cod-fishing in the bay and adjacent waters has been almost phenomenal. The fish were abundant on the mussel-beds in the West Passage when the traps were set in the spring, and in the fall had returned in considerable numbers. The fish were in excellent condition.

It is a question whether the increasing abundance of cod in our waters is an unmixed blessing, for it is certain that this fish is a most destructive enemy to the lobster. The commission has many specimens of lobsters taken from the stomach of the cod. One specimen from a cod caught off Nantucket on November 1, 1900, measured five inches in length.

## VI. Continued Examination of the Physical and Biological Conditions of the Water of the Bay, Begun in 1898.

Notes on the occurrence of various species of animals found

while exploring the shore, dredging the bottom, and skimming the surface of the water are being filed for future use, and a daily record of the temperature and specific gravity of the water at the house-boat in Wickford was kept from April to the middle of September.

## VII. A Preliminary Survey of the Shore of the Bay for the Purpose of Determining Those Portions Which are Most Productive of Young Seed-Clams.

The fact that clams set exceedingly thick in limited localities so that they can be taken in quantities, and the importance of this fact in connection with the clam-industry, has been pointed out in the report of last spring and is also referred to in the present report.

After the arrival of the launch a large portion of the shore of the bay was examined for the purpose of locating such places. Several localities were discovered, although it was evident that, in general, the set of the past year was far less abundant than that of 1899. It is proposed to continue the examinations of the shore for this and other purposes, and to embody the results in a future report.

## VIII. A Continuation of the Investigation on the Life-History of the Clam, Methods of Artificial Propagation and Cultivation.

This investigation has been continued at the laboratory at Wickford, and some of the questions left over from last year have been satisfactorily answered. The commission is indebted to the U. S. Fish Commission for assistance in many of the experiments, the report of which is given in the following pages:

# OBSERVATIONS ON THE SOFT-SHELL CLAM.

*(SECOND PAPER.)*

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An account of the observations on the breeding habits, rate of growth under various conditions, of the habits of the young before and after setting, and of the experiments made to ascertain the possibilities of the artificial culture of clams, was given in the Report of 1899, pp. 20–42. In the course of the investigations recorded in the previous report, questions arose which could not at that time be answered satisfactorily, and they were deferred to a subsequent time.

It is the purpose of the present paper, therefore, to record merely the progress made during the past season without reviewing the account of previous observations.

The account will be given, as concisely as possible, in three chapters, viz.: Breeding, Rate of Burrowing, and Rate of Growth. The contents of these are as follows:

BREEDING.

1. How old are the clams when they first breed?
2. Is there a second breeding season?
3. Is artificial fertilization of the clam possible and practicable for obtaining spat in quantity?
4. Do clams change their sex as they grow older?
5. What are the best methods for obtaining young clams for planting?

### RATE OF BURROWING.

A statement of the bearing of the habit of burrowing on the problem of clam-culture.

A statement in tabulated form of experiments made to determine the effect of varying conditions on the rate of burrowing.

A summary of results.

Conclusions.

### RATE OF GROWTH.

The record of a series of new experiments made to ascertain the rate of growth of clams of various ages planted under varying conditions. The record will be presented in tabulated form, and the inferences drawn will be stated in the text.

### FIGURES.

A series of figures reproduced from life-size photographs, showing some of the new results in respect to the rate of growth of the clam.

## Breeding.

*How old are clams when they first breed?*

This problem was left open at the time of writing the last Report, but now can be definitely answered.

The clams which were described in the last report as setting in such abundance on Cornelius Island were kept under observation throughout the year, and in May were found to be full of ripe sexual products. On May 25, 1900, a large number were carefully examined, and all were ready to spawn. In order to be sure that the eggs were ripe, artificial fertilization was tried, and the result was as satisfactory as it has ever been with clams. From 5 per cent. to 10 per cent of the eggs developed normally. Both the

males and females in these experiments were less than two inches long and were undoubtedly of the set of 1899.

On June 7, a large number of specimens from the same locality had extruded practically all their eggs or sperm, some had extruded a portion, and others were still full of sexual products.

In connection with this observation there are two minor points of interest namely, first, that the small clams spawned before the larger ones; and, second, in clams of the same size, those near high water spawned before those at low water.

In conclusion, and in answer to the original question, it may be said with certainty that clams spawn during the first year of their life.

*Is there a second breeding season?*

Between the regular spawning season of June, 1899, and June, 1900, there was another distinct breeding season, probably in the fall of 1899. The set resulting from this was first discovered in April, 1900, when the largest specimens were about one-quarter inch long. The evidence that this was a fall set is that every specimen had the surface of the shell next to the hinge corroded and distinctly marked off from the new growth. This condition is never seen in the summer set, but would be accounted for if the clams lay for months with almost no growth. The mark persists in these specimens until they are more than an inch long. By the tenth of June some of these had grown to 30mm. in length and were as long as many sexually mature year-old specimens. Photographs of specimens taken May, 1900, are shown in figure 7.

*Is artificial fertilization of the clam possible and practicable for obtaining spat in quantity?*

I have tried numerous experiments on the artificial fertilization of clams, but with small success. It has not been possible to induce them to lay their eggs like the scallops, and when the eggs are cut out and fertilized, only a small proportion, 10 per cent. to 20 per cent., will develop.

While, therefore, it cannot be said, at present, that artificial fertilization in case of clams is impossible, the results so far are not encouraging.

*Do clams change their sex as they grow older?*

This question has been raised in regard to the clam and is a legitimate one, inasmuch as several accounts have been given by very high authorities that in certain other animals this curious phenomenon occurs. In these cases the animal is at first a male, and later a female. Between the two conditions there is a hermaphrodite stage according the recent researches of W. M. Wheeler on one of these animals, *Myzostoma*. This animal is potentially hermaphrodite from the first, but in the early stages the eggs do not ripen, although the sperm does, so that they are practically males.

A large number of clams have been very carefully examined by means of microscopic sections, or by a microscopic examination of the living specimens. These observations may later be published in detail in connection with appropriate researches, but the general conclusion arrived at is that there is no such phenomenon present among the clams, or, in other words, that the clams do not change their sex.

In the examination of the living specimens there seemed to be evidence of occasional hermaphroditism, but it is probable that it rarely, if ever, occurs.

*What are the best methods of obtaining young clams for planting?*

The importance of obtaining spat in quantity is fully recognized by the oyster culturists, and immense sums of money have been expended in experiments in this line. For successful clam-culture it is quite essential that the small clams be obtained in abundance and with tolerable certainty.

In the case of both clams and oysters the abundance of the set is subject to great variation from year to year. In the year 1899, for example, the clam-set was unusually large in nearly all parts of

the bay; in 1900 the clam-set was small and the oyster-set exceedingly heavy, so that nearly every available object in the bay was covered thickly with young oysters. They were even a nuisance from the fact that they covered over the marketable oysters.

An account is given in the last Report of the abundance of the clam-set of 1899 and the means of taking the small clams at the best size for sowing, one-half inch, more or less, in length. These could be found in great quantities in numerous localities, sometimes where they could not come to maturity owing to the shifting sand. They were thickest on sandy points which, jutting far out from the shore, were swept at high water by the tides. In localities of this sort it was shown to be feasible to collect the spat during July and the first of August by means of a sieve. As many as ten quarts, twenty or thirty thousand specimens, were taken with one hand-sieve in about half an hour. This method is satisfactory, therefore, when the clams are thick and the soil is sandy.

*Artificial set.*—There were several observations made a year ago which, taken together, pointed to the possibility of obtaining what might be called an "artificial set:" (1) The natural set is very uneven in its distribution. In one locality over 20,000 clams were taken from one square yard, while a few rods away, at the same level, and in the same kind of soil, there were only a very few scattering ones to be found. (2) The areas where the set was thick were situated with peculiar relation to the direction of the tidal currents. (3) It was found from continuous observation of the skimmings taken at the surface of the water that from the last of May to the first of July the free-swimming larvæ were always and everywhere present in greater or less abundance. (4) It was learned from watching the free-swimming young which had been captured that the older ones showed a distinct tendency to stop swimming and to settle to the bottom when they came in contact with a solid body or when the dish was jarred. The same tendency had been noticed in the star-fish larvæ when they were ready to undergo their metamorphoses; it is also true of some marine worms, *e. g.*, *Amphitrite*, and probably obtains in a large number of swimming

larvæ. The explanation of this instinct is doubtless that by sticking to solid objects, such as stones, shells, sea-weed, etc., the young stand a better chance of surviving than if they settled indiscriminately to the bottom to be lost in the mud and slime.

These four facts taken together suggested the possibility of arranging an artificial barrier which would precipitate and hold the young as they are carried against it by the tides.

Of several experiments in this direction one was successful beyond all expectations. About the middle of May a small box without a bottom was placed on the shore at about half-tide mark, and covered with galvanized wire gauze having a mesh the size of mosquito netting. On the 14th of August the box was examined and was found to contain a set of small clams so thick that they practically touched one another. From an area of one square foot 1,302 clams were taken, the total bulk amounting to three-quarters of a pint. Some of them were preserved and are photographed natural size in figure 1. Most of them were taken to the house-boat and sowed in a sand-box which was suspended about 18 inches below the surface of the water. The growth was extremely rapid, as may be seen by reference to page 43.

This result is of especial value from the fact that there were practically no clams to be found in the vicinity of the box, and from the fact that the season was comparatively a poor one for the clam-set.

If the experiment proves all that it promised, the problem of obtaining a supply of seed-clams is solved. There may, moreover, be other and cheaper methods of catching the spat and precipitating a set than that of using wire gauze. In two or three cases a considerable set was caught in sand-boxes which lay on shore uncovered but with sides projecting above the surface of the sand on the inside as well as on the outside, and in one of the land tiles which projected a few inches above the surface 13 clams of this year's set were found (the tiles were only 2 or 3 inches in diameter). Further experiments will be tried during the coming season.

## 2. Rate of Burrowing.

Among the habits which are of economic importance, either in view of clam-culture or of replenishing the natural beds, the habit of burrowing deserves a conspicuous place. In their early life the clams are free-swimming animals, but soon "set," and after they are several weeks old will never again thrive, however well they may be protected, unless they are embedded in the soil. The first attempt at burrowing may be made as soon as the clams quit the swimming habit, or it may be postponed for a month or two, according as they happen to fall upon good ground or to set upon some object at a distance from the soil. At any time during the first two months of their existence the clams all have a remarkable capacity for rapid burrowing, a capacity which decreases gradually as the individual grows older. Indeed, the necessity for burrowing is greater in the small individuals, for they cannot go deep and they are frequently washed or dug out.

The experiments which are given below in tabulated form were made for the purpose of ascertaining (a) how much injury is done by continually digging up clams which are not noticed by the digger, or are not large enough to eat; and (b) under what conditions it would be feasible and practicable to sow clams rather than to plant them, in case one undertook clam cultivation on a large scale.

The first table records the experiments made at various times during the summer, and under many varying conditions.

## Table No. I.

| Date. | Hour. | Number sowed. | Year of set. | Length in mm. | Bulk—number per quart. | Time out of soil. | How kept. | Soil. | Soil dug up? | Date of examination. | Hour of examination. | Time between sowing and examination. | Number exposed. | Per cent. burrowed. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May 14 | ........ | 216 | 1899 | ........ | 288 | 24? hours | dry | sand box | yes | May 18 | ........ | 4 days | 4 | 98 |
| May 14 | ........ | 20 | 1889 | ........ | 256 | 24? hours | dry | sand box | yes | May 18 | ........ | 4 days | 0 | 100 |
| May 14 | ........ | 10 | 1899 | 44-50 | ........ | 24? hours | dry | sand box | yes | May 18 | ........ | 4 days | 1 | 90 |
| May 14 | ........ | 8 | 1899 | 62 | ........ | 24? hours | dry | sand box | yes | May 18 | ........ | 4 days | 1 | 88 |
| May 14 | ........ | 20 | 1899 | ........ | 176 | 24? hours | dry | sand box | yes | May 18 | ........ | 4 days | 2 | 90 |
| May 23 | 9.30 10.30 A.M. | 8 | ........ | 76 | ........ | 24? hours | dry | sand box | yes | May 23 | 7.40 P.M. | 10 hours | 3 | 63 |
| May 23 | 9.30 10.30 A.M. | 20 | ........ | 64 | ........ | 24? hours | dry | sand box | yes | May 23 | 7.40 P.M. | 10 hours | 3 | 85 |
| May 24 | 9.30 A.M. | 56 | ........ | ........ | 176 | 24 hours | dry | sand box | yes | May 24 | 8.30 P.M. | 11 hours | 2 | 97 |
| May 23 | 9.30-10 30 A M | 14 | ........ | 56 | ........ | 24? hours | dry | sand box | yes | May 23 | 7.40 P.M. | 10 hours | 1 | 93 |
| May 23 | 9.30-10.30 A.M. | 8 | ........ | 50 | ........ | 24? hours | dry | sand box | yes | May 23 | 7.40 P.M. | 10 hours | 0 | 100 |
| May 23 | 9.30 10.30 A.M. | 28 | ........ | 44 | ........ | 24? hours | dry | sand box | yes | May 23 | 7.40 P.M. | 10 hours | 2 | 93 |
| June 13 | ........ | 35 | ........ | ........ | 160 | 24? hours | dry | sand box | yes | June 14 | ........ | 24? hours | 2 | 94 |
| June 13 | ........ | 35 | ........ | ........ | 240 | 24? hours | dry | sand box | yes | June 14 | ........ | 24? hours | 2 | 94 |
| May 24? | 9 30 A.M. | 79 | 1899 | ........ | 256 | 24? hours | dry | sand box | yes | June 24? | 8.30 P.M. | 11 hours | 1 | 99 |
| May 24? | 9 30 A.M. | 93 | 1899 | ........ | 256 | 24? hours | dry | sand box | yes | June 24? | 8.30 P.M. | 11 hours | 1 | 99 |
| Aug. 3 | 11.40 A.M. | 400 | 1900 | 17 20 | 1200 | 24 hours | water | sand box | yes | Aug. 3 | 11.55 A.M. | 15 min. | 200 + | 50 |
| | | | | | | | | | | Aug. 3 | 12.10 P.M. | 30 min. | ........ | 75± |
| | | | | | | | | | | Aug. 3 | 3.00 P.M. | 3½ hours | 65 | 84 |

TABLE NO. I.—Continued.

| Date. | Hour. | Number sowed. | Year of set. | Length in mm. | Bulk number per quart. | Time out of soil. | How kept. | Soil. | Soil dug up? | Date of examination. | Hour of examination. | Time between sowing and examination. | Number exposed. | Per cent. burrowed. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aug. 3 | 12.15 P.M. | 401 | 1900 | 17-20 | 1200 | 24 hours | water | sand box | yes | Aug. 3 | 12.25 P.M. | 10 min. | .......... | 50+ |
| | | | | | | | | | | Aug. 3 | 3 P.M. | 2¾ hours | 50 | 88 |
| | | | | | | | | | | Aug. 4 | ........... | 24 hours | 38 | 91 |
| Aug. 7 | 4 P.M. | 509 | 1900 | 12-25 | 1200+ | 6 hours | water | sand box | yes | Aug. 8 | 12 NOON. | 20 hours | 50 | 91 |
| Aug. 7 | 4 P.M. | 500 | 1900 | 12-25 | 1200± | 6 hours | water | sand box | yes | Aug. 8 | 12 NOON. | 20 hours | 29 | 94 |
| Aug. 14 | 12 NOON. | 1241 | 1900 | 6-18 | 3470 | 0 hours | ........ | sand box | yes | Aug. 14 | 12.20 P.M. | 20 min. | .......... | 99 |
| Aug. 14 | 12.30 P.M. | 760 | 1900 | ........ | 760 | 24 hours | water | sand box | yes | Aug. 14 | 1.30 P.M. | 1 hour | .......... | 83± |
| Aug. 14 | 12.30 P.M. | 380 | 1900 | ... .... | 760 | 24 hours | water | sand box | yes | Aug. 14 | 1.30 P.M. | 1 hour | 0 | 100 |
| Aug. 24 | — A.M. | 200 | 1900 | ........ | 800 | 2 days | water | sand box | yes | Aug. 24 | — P.M. | 12 hours | 2 | 99 |
| June 7 | 9.30-10.30 A.M. | 832 | 1899 | ........ | 208 | 24 hours | dry | gravel | no | June 7 | 7.30 P.M. | 10 hours | 80 | 90 |
| | | | | | | | | | | June 8 | 10 A.M. | 24 hours | 55 | 93 |
| June 7 | 9.30-10.30 A.M. | 768 | 1899 | ........ | 128 | 24 hours | dry | gravel | no | June 7 | 7.30 P.M. | 10 hours | 120 | 84 |
| | | | | | | | | | | June 8 | 10 A.M. | 24 hours | 120 | 83 |
| June 11 | 11+ A.M. | 87 | 1899 | ........ | 160 | 1+ hour | dry | gravel | no | June 12 | 10 A.M. | 24+ hours | 5 | 94 |
| June 11 | 11+ A.M. | 56 | 1899 | ........ | 160 | 24 hours | dry | gravel | no | June 12 | 10 A.M. | 24+ hours | 10 | 82 |
| June 11 | 11+ A.M. | 75 | 1899? | ........ | 160 | 24 hours | water | gravel | no | June 12 | 10 A.M. | 24+ hours | 5 | 93 |
| June 11 | 11+ A.M. | 228 | 1899 | ........ | 228 | 1+ hour | dry | gravel | no | June 12 | 10-11 A.M. | 24 hours | 18 | 92 |

TABLE NO. I.—Continued.

| Date. | Hour. | Number sowed. | Year of set. | Length in mm. | Bulk—number per quart. | Time out of soil. | How kept. | Soil. | Soil dug up? | Date of examination. | Hour of examination. | Time between sowing and examination. | Number exposed. | Per cent. burrowed. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| June 11 | 11+ A.M. | 112 | 1899 | ........ | 240 | 24 hours | dry | gravel | no | June 12 | 10-11 A.M. | 24 hours | 31 | 72 |
| June 11 | 11+ A.M. | 100 | 1899 | ........ | 240 | 24 hours | water | gravel | no | June 12 | 10-11 A.M. | 24 hours | 14 | 86 |
| June 12 | 10.30 A.M. | 125 | 1899? | ........ | 160 | 1± hour | dry | hard sand | no | June 13 | 11 A.M. | 24 hours | 56 | 55 |
| June 12 | 10.30 A.M. | 88 | 1899? | ........ | 160 | 24 hours | dry | hard sand | no | June 13 | 11 A.M. | 24 hours | 41 | 54 |
| June 12 | 10.30 A.M. | 32 | 1899 | ........ | 160 | 24 hours | water | hard sand | no | June 13 | 11 A.M. | 24 hours | 12 | 63 |
| June 12 | 10.30 A.M. | 125 | 1899 | ........ | 240 | 1± hour | dry | hard sand | no | June 13 | 11 A.M. | 24 hours | 61 | 51 |
| June 12 | 10.30 A.M. | 93 | 1899 | ........ | 240 | 24 hours | dry | hard sand | no | June 13 | 11 A.M. | 24 hours | 36 | 62 |
| June 12 | 10.30 A.M. | 110 | 1899 | ........ | 240 | 24 hours | water | hard sand | no | June 13 | 11 A.M. | 24 hours | 32 | 71 |
| June 12 | ............... | 160 | 1899 | ........ | 160 | ........... | dry | hard sand | yes | June 13 | .......... | 24? hours | 61 | 62 |
| June 12 | ............... | 60 | 1899 | ........ | 160 | ........... | dry | hard sand | no | June 13 | ........... | 24? hours | 42 | 30 |
| June 12 | ............... | 160 | 1899 | ........ | 240 | ........... | dry | hard sand | yes | June 13 | ........... | 24? hours | 65 | 60 |
| June 12 | ............... | 60 | 1899 | ........ | 240 | ........... | dry | hard sand | no | June 13 | ........... | 24? hours | 32 | 47 |
| June 7 | — A.M. | 173 | ........ | ........ | 86 | ........... | dry | soft sand | yes? | June 7 | 7.30 P.M. | ........... | 100 | 43 |
| | | | | | | | | | | June 8 | ........... | 24? hours | 100 | 43 |
| June 13 | ............... | 100 | ........ | ........ | 160 | ........... | dry | hard sand | no | June 14 | ........... | 24? hours | 26 | 74 |
| June 13 | ............... | 100 | ........ | ........ | 160 | ........... | dry | hard sand | yes | June 14 | ........... | 24? hours | 14 | 86 |
| June 13 | ............... | 100 | ........ | ........ | 240 | ........... | dry | hard sand | no | June 14 | ........... | 24? hours | 21 | 79 |
| June 13 | ............... | 100 | ........ | ........ | 240 | ........... | dry | hard sand | yes | June 14 | ........... | 24? hours | 16 | 84 |

This tabulated statement does not require particular explanation. By glancing over the results of the various experiments made at different times, a general idea will be obtained of the proportion of clams which may be expected to burrow when they are sown on the surface.

On September 13, 14, and 15 a new series of experiments were made on the burrowing habits, in a more systematic way than had been done heretofore. The clams selected for these experiments were separated into four classes which are given successively in the tables, viz.:

| | | |
|---|---|---|
| I. | Large, 50-70mm. (2–2¾ inches) in length; | Set of 1899 or previous to that date. |
| II. | Medium, 35-50mm.; | |
| III. | Small, 25-35mm.; | |
| IV. | Small set of 1900, 20-30mm. | |

To insure the protection of the clams while exposed, and to prevent them from washing away, boxes with 8-inch sides and ½-inch wire mesh bottoms were inverted over the beds. All the clams were sowed on the surface just as the tide was beginning to rise.

The attempt was made to determine the value of the following conditions for each class of clams:

| | | | | |
|---|---|---|---|---|
| *a.* | Sowing clams immediately after digging. | | | |
| *b.* | " | " | kept 24 hours out of water (dry). | |
| *c.* | " | " | " " | in sea-water. |
| *d.* | " | " | in soil softened by previous digging. | |
| *e.* | " | " | " | not dug up. |
| *f.* | " | " | in gravel. | |
| *g.* | " | " | in sand. | |

For convenience in referring to the tables, these letters are placed in the first column.

TABLE NO. II.

| CLASS I. | Date. | Hour. | Number sowed. | Year of set. | Length in mm. | Time out of soil. | How kept. | Soil. | Soil dug up? | Date of examination. | Hour of examination. | Time between sowing and examination. | Number exposed. | Per cent. burrowed. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *a. d.* | Sept. 13 | 4-5 P.M. | 25 | 1898? | 50-70 | abt. 1 hour | dry | sand | yes | Sept. 14 | 8-9 A.M. | 16 hours | 11 | (56) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 8 | 68 |
| *a. e.* | Sept. 13 | 4-5 P.M. | 25 | 1899? | 50-70 | 1 hour | dry | sand | no | Sept. 14 | 8-9 A.M. | 16 hours | 9 | (64) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 6 | 76 |
| *b. d.* | Sept. 13 | 4-5 P.M. | 25 | 1899? | 50-70 | 24 hours | dry | sand | yes | Sept. 14 | 8-9 A.M. | 16 hours | 8 | (68) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 2 | 92 |
| *b. e.* | Sept. 13 | 4-5 P.M. | 25 | 1899? | 50-70 | 24 hours | dry | sand | no | Sept. 14 | 8-9 A.M. | 16 hours | 18 | (28) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 13 | 48 |
| *c. d.* | Sept. 13 | 4-5 P.M. | 25 | 1899? | 50-70 | 24 hours | water | sand | yes | Sept. 14 | 8-9 A.M. | 16 hours | 8 | (68) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 3 | 88 |
| *c. e.* | Sept. 13 | 4-5 P.M. | 25 | 1899? | 50-70 | 24 hours | water | sand | no | Sept. 14 | 8-9 A.M. | 16 hours | 16 | (36) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 12 | 52 |
| *b. e.* | Sept. 15 | 6-6.30 P.M. | 25 | 1899? | 50-70 | 24 hours | dry | gravel | no | Sept. 16 | 9.30 A.M. | 15 hours | 13 | (48) |
| | | | | | | | | | | Sept. 17 | 8 A.M. | 40 hours | 9 | 64 |
| *c. e.* | Sept. 15 | 6-6.30 P.M. | 25 | 1899? | 50-70 | 24 hours | water | gravel | no | Sept. 16 | 9.30 A.M. | 15 hours | 17 | (32) |
| | | | | | | | | | | Sept. 17 | 8 A.M. | 40 hours | 7 | 72 |
| | | | | | | | | | | | Average percentage | | = | 70 |

TABLE No. II.—Continued.

| CLASS II. | Date. | Hour. | Number sowed. | Year of set. | Length in mm. | Time out of soil. | How kept. | Soil. | Soil dug up? | Date of examination. | Hour of examination. | Time between sowing and examination. | Number exposed. | Per cent. burrowed. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *a. d.* | Sept. 13 | 4-5 P.M. | 25 | 1899? | 35-50 | 1 hour ± | dry | sand | yes | Sept. 14 | 8-9 A.M. | 16 hours | 4 | (84) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 2 | 92 |
| *a. c.* | Sept. 13 | 4-5 P.M. | 25 | 1899? | 35-50 | 1 hour + | dry | sand | no | Sept. 14 | 8-9 A.M. | 16 hours | 4 | (84) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 0 | 100 |
| *b. d.* | Sept. 13 | 4-5 P.M. | 25 | 1899? | 35-50 | 24 hours | dry | sand | yes | Sept. 14 | 8-9 A.M. | 16 hours | 3 | (88) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 1 | 96 |
| *b. c.* | Sept. 13 | 4-5 P.M. | 25 | 1899? | 35-50 | 24 hours | dry | sand | no | Sept. 14 | 8-9 A.M. | 16 hours | 13 | (48) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 10 | 60 |
| *c. d.* | Sept. 13 | 4-5 P.M. | 25 | 1899? | 35-50 | 24 hours | water | sand | yes | Sept. 14 | 8-9 A.M. | 16 hours | 4 | (84) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 1 | 96 |
| *c. c.* | Sept. 13 | 4-5 P.M. | 25 | 1899? | 35-50 | 24 hours | water | sand | no | Sept. 14 | 8-9 A.M. | 16 hours | 7 | (72) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 4 | 84 |
| *b. e.* | Sept. 15 | 6-6.30 P.M. | 25 | 1899? | 35-50 | 24 hours | dry | gravel | no | Sept. 16 | 9.30 A.M. | 15 hours | 10 | (60) |
| | | | | | | | | | | Sept. 17 | 8 A.M. | 40 hours | 5 | 80 |
| *c. e.* | Sept. 15 | 6-6.30 P.M. | 25 | 1899? | 35-50 | 24 hours | water | gravel | no | Sept. 16 | 9.30 A.M. | 15 hours | 12 | (52) |
| | | | | | | | | | | Sept. 17 | 8 A.M. | 40 hours | 7 | 72 |
| | | | | | | | | | | | Average percentage | | = | 86¼ |

## TABLE NO. II.—Continued.

| CLASS III. | Date. | Hour. | Number sowed. | Year of set. | Length in mm. | Time out of soil. | How kept. | Soil. | Soil dug up? | Date of examination. | Hour of examination. | Time between sowing and examination. | Number exposed. | Per cent. burrowed. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *a. d.* | Sept. 13 | 4-5 P.M. | 25 | 1899 | 25-35 | 1 hour or less | dry | sand | yes | Sept. 14 | 8-9 A.M. | 16 hours | 1 | (96) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 0 | 100 |
| *a. e.* | Sept. 13 | 4-5 P.M. | 25 | 1899 | 25-35 | 1 hour or less | dry | sand | no | Sept. 14 | 8-9 A.M. | 16 hours | 1 | (96) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 0 | 100 |
| *b. d.* | Sept. 13 | 4-5 P.M. | 25 | 1899 | 25-35 | 24 hours | dry | sand | yes | Sept. 14 | 8-9 A.M. | 16 hours | 1 | (96) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 0 | 100 |
| *b. e.* | Sept. 13 | 4-5 P.M. | 25 | 1899 | 25-35 | 24 hours | dry | sand | no | Sept. 14 | 8-9 A.M. | 16 hours | 4 | (84) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 2 | 92 |
| *c. d.* | Sept. 13 | 4-5 P.M. | 25 | 1899 | 25-35 | 24 hours | water | sand | yes | Sept. 14 | 8-9 A.M. | 16 hours | 6 | (76) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 2 | 92 |
| *c. e.* | Sept. 13 | 4-5 P.M. | 25 | 1899 | 25-35 | 24 hours | water | sand | no | Sept. 14 | 8-9 A.M. | 16 hours | 14 | (44) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 8 | 68 |
| *b. e.* | Sept. 15 | 6-6.30 P.M. | 25 | 1899 | 25-35 | 24 hours | dry | gravel | no | Sept. 16 | 9.30 A.M. | 15 hours | 5 | (80) |
| | | | | | | | | | | Sept. 17 | 8 A.M. | 40 hours | 0 | 100 |
| *c. e.* | Sept. 15 | 6-6.30 A.M. | 25 | 1899 | 25-35 | 24 hours | water | gravel | no | Sept. 16 | 9.30 A.M. | 15 hours | 13 | (48) |
| | | | | | | | | | | Sept. 17 | 8 A.M. | 40 hours | 7 | 72 |
| | | | | | | | | | | | Average percentage | | = | 90½ |

TABLE No. II.—Continued.

| CLASS IV. | Date. | Hour. | Number sowed. | Year of set. | Length in mm. | Time out of soil. | How kept. | Soil. | Soil dug up? | Date of examination. | Hour of examination. | Time between sowing and examination. | Number exposed. | Per cent. burrowed. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *a. d.* | Sept. 13 | 4-5 P.M. | 50 | 1900 | 20-30 | 1 hour or less | dry | sand | yes | Sept. 14 | 8-9 A.M. | 16 hours | 4 | (92) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 3 | 94 |
| *a. c.* | Sept. 13 | 4-5 P.M. | 50 | 1900 | 20-30 | 1 hour or less | dry | sand | no | Sept. 14 | 8-9 A.M. | 16 hours | 2 | (96) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 0 | 100 |
| *b. d.* | Sept. 13 | 4-5 P.M. | 50 | 1900 | 20-30 | 24 hours | dry | sand | yes | Sept. 14 | 8-9 A.M. | 16 hours | 9 | (82) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 3 | 94 |
| *b. c.* | Sept. 13 | 4-5 P.M. | 50 | 1900 | 20-30 | 24 hours | dry | sand | no | Sept. 14 | 8-9 A.M. | 16 hours | 8 | (84) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 2 | 96 |
| *c. d.* | Sept. 13 | 4-5 P.M. | 50 | 1900 | 20-30 | 24 hours | water | sand | yes | Sept. 14 | 8-9 A.M. | 16 hours | 9 | (82) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 6 | 88 |
| *c. c.* | Sept. 13 | 4-5 P.M. | 50 | 1900 | 20-30 | 24 hours | water | sand | no | Sept. 14 | 8-9 A.M. | 16 hours | 21 | (56) |
| | | | | | | | | | | Sept. 14 | 5 P.M. | 24 hours | 20 | 60 |
| *b. c.* | Sept. 15 | 6-6.30 P.M. | 50 | 1900 | 20-30 | 24 hours | dry | gravel | no | Sept. 16 | 9.30 A.M. | 15 hours | 3 | (94) |
| | | | | | | | | | | Sept. 17 | 8 A.M. | 40 hours | 1 | 98 |
| *c. c.* | Sept. 15 | 6-6.30 P.M. | 50 | 1900 | 20-30 | 24 hours | water | gravel | no | Sept. 16 | 9.30 A.M. | 15 hours | 23 | (54) |
| | | | | | | | | | | Sept. 17 | 8 A.M. | 40 hours | 14 | 72 |
| | | | | | | | | | | | | Average percentage | = | 87¾ |

An examination of the experiments here tabulated shows some interesting results which may be briefly stated as follows.

Of the three classes of clams which were more than one year old the smaller specimens were most successful in burrowing, the middle ones next, and the largest clams least successful. The fourth class composed of specimens a few months old were slightly less successful than the third.

| | | | |
|---|---|---|---|
| Of the I (50–70mm.) class, under all conditions | 70 | per cent. | burrowed. |
| II (35–50mm.) | 85 | per cent. | " |
| III (25–35mm.) | 90.5 | per cent. | " |
| IV (20–30mm., 1900) | 87.7 | per cent. | " |

The effects of the varying conditions may be stated as follows:

(*a*) Planted immediately after digging (1 hour or less).

| | | | |
|---|---|---|---|
| Class I | 72 | per cent. | burrowed. |
| " II | 96 | per cent. | " |
| " III | 100 | per cent. | " |
| " IV | 97 | per cent. | " |

Average per cent. = 91.2

(*b*) Dry 24 hours.

| | | | |
|---|---|---|---|
| Class I | 68 | per cent. | burrowed. |
| " II | 78.6 | per cent. | " |
| " III | 97.3 | per cent. | " |
| " IV | 96 | per cent. | " |

Average per cent. = 84.9

(*c*) Kept in water 24 hours between digging and sowing.

| | | | |
|---|---|---|---|
| Class I | 70.6 | per cent. | burrowed. |
| " II | 84.0 | per cent. | " |
| " III | 77.3 | per cent. | " |
| " IV | 73.3 | per cent. | " |

Average per cent. = 76.3

(*d*) Soil dug up before sowing.

| | | |
|---|---|---|
| Class I | 82.6 | per cent. burrowed. |
| " II | 94.6 | per cent. " |
| " III | 97.3 | per cent. " |
| " IV | 92 | per cent. " |
| Average per cent. = | 91.6 | |

(*e*) Soil not dug up before sowing.

| | | |
|---|---|---|
| Class I | 62.4 | per cent. burrowed. |
| " II | 79.2 | per cent. " |
| " III | 86.4 | per cent. " |
| " IV | 85.2 | per cent. " |
| Average per cent. = | 78.3 | |

(*f*) Sand.

| | | |
|---|---|---|
| Class I | 70.6 | per cent. burrowed. |
| " II | 88 | per cent. " |
| " III | 92 | per cent. " |
| " IV | 88.6 | per cent. " |
| Average per cent. = | 84.8 | |

(*g*) Gravel.

| | | |
|---|---|---|
| Class I | 68 | per cent. burrowed. |
| " II | 76 | per cent. " |
| " III | 86 | per cent. " |
| " IV | 84.5 | per cent. " |
| Average per cent. = | 78.7 | |

Summary: The average per cent. of all clams............. 83.4 burrowed.

| | |
|---|---|
| The average per cent. of those planted immediately after digging | 91.2 |
| " " of those dry 24 hours after digging | 84.9 |
| " " of those in water 24 hours after digging | 76.3 |
| " " of those in dug up soil before sowing | 91.6 |
| " " of those in soil not dug up before sowing | 78.3 |

The general conclusion of the chapter is—that clams of an inch or less in length can be sown broadcast with little loss from their not burrowing; that as they increase in size their capacity for burrowing decreases, so that for larger clams planting and covering is necessary; clams are best sown as soon as possible after digging, but if they are to be transplanted from one place to another they are better kept dry than in water.

### 3. Rate of Growth.

As was pointed out in the report of last year, this is an important question in view of any attempt to regulate the natural clam production and to rear clams artificially.

It was clearly proved by the experiments of 1899 that the rate of growth of the clam, like that of the star-fish, varied within wide limits, according to the conditions of life, and a number of experiments were undertaken during the last summer to furnish more definite data bearing upon this question.

These experiments were begun in April, and during the early part of the season the clams used were those of the set of 1899, and were, therefore, nearly a year old.

According to the methods of planting, the experiments were divided into three classes:

1. Clams planted in beds on the shore.

2. Clams planted in boxes, about 6 x 4 feet and 8 inches deep, filled with sand and anchored in various places.

3. Clams planted in boxes, with the bottom made of wire netting ($\frac{1}{2}$-inch mesh) and filled with sand. The object of this scheme was to allow the sand to be sifted out leaving the clams for examination.

Owing to an unaccountable mortality of the clams during the latter part of the summer (a problem for further investigation),

many of the experiments were never finished. Later in the season, after the arrival of the set of 1900, further experiments were made with the young clams.

A brief record of some of these experiments, including the essential conditions and the results, is given in the following tables:

| Experiment number. | Year of set. | Date of planting. | Length of planting in millemeters. | Bulk number per quart. | No. per foot. | Position in tide-water. | Depth planted. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 1 bed ....... | 1899 | April 21 | .......... | 192 | 16 | Half tide.......... | Four inches. | 1 quart planted............. |
| 2 beds...... | 1899 | April 25 | .......... | 192 | 16 | " .......... | " | " " ............. |
| 3 " ....... | 1899 | April 25 | *25-38 | 176 | 16 | " .......... | " | " " ............. |
| 4 " ....... | 1899 | April 27 | .......... | 160 | 16 | Just below half tide............... | " | " " ............. |
| 5 " ...... | 1899 | April 28 | .......... | 192 | 16 | Low tide.......... | " | " " ............. |
| 6 " ....... | 1899 | May 10 | *32-41 | 140 | 32 | Half tide .......... | Just covered. | " " ............. |
| 7 " ....... | 1899 | May 10 | .......... | 228 | 32 | " ........... | Four inches. | 1½ pints planted........... |
| 8 " ....... | 1899 | May 10 | .......... | 256 | 32 | " ........... | " | " " ............ |
| 9 " ....... | 1899 | May 14 | .......... | 96 | 6 | " ........... | Just covered. | 1 pint planted............... |
| 10 boxes...... | 1899 | May 3 | .......... | 170 | .... | Low tide.. ........ | Four inches. | 1 quart planted............. |
| 11 " ...... | 1899 | May 5 | .......... | 200 | .... | Just below low tide | " | " " ............. |
| 12 " ...... | 1899 | May 5 | .......... | 266 | .... | Under 1 ft. of water at low tide ...... | " | " " ............. |
| 13 " ...... | 1899 | May 11 | .......... | 175 | .... | Under 3 ft. of water at low tide ...... | " | " " ............. |
| 14 " ...... | 1899 | May 11 | .......... | 200 | .... | Low tide.......... | " | " " ............. |
| 15 wire boxes | 1899 | May 24 | .... ..... | 255 | .... | Half tide.......... | " | " " ............. |
| 16 " | 1899 | May 24 | .......... | 176 | .... | " .......... | " | 2 quarts planted............ |
| 17 " | 1899 | May 25 | .......... | 211 | .... | " .......... | " | 3½ pints planted........... |
| 18 " | 1899 | May 25 | .......... | 140(?) | .... | " .......... | " | 1 quart planted.............. |
| 19 " | 1899 | June 9 | .......... | 128 | .... | 2 ft. water at low tide.............. | " | .............. .............. |
| 20 boxes..... | 1900 | Aug. 3 | 13-29 | 1,200 | .... | Low tide.......... | Sowed....... | Preserved...... ............ |
| 21 " ...... | 1900 | Aug. 3 | 13-20 | 1,200 | .... | Near high tide..... | " ....... | " .................. |
| 22 " ...... | 1900 | Aug. 7 | 12-31 | 1,200 | .... | Low tide.......... | " ....... | " .................. |
| 23 " ...... | 1900 | Aug. 7 | 12-31 | 1,200 | .... | Near high tide..... | " ....... | " .................. |
| 24 " ...... | 1900 | Aug. 14 | .......... | 760 | .... | House-boat, 1½ ft. under water..... | " ...... | Compare experiment No. 25. |
| 25 " ...... | 1900 | Aug. 14 | .......... | 760 | .... | House-boat, 8 ft. below water..... | .............. | Compare experiment No. 24. |
| 26 " ...... | 1900 | Aug. 14 | 5-17 | 3,472 | .... | House-boat, 1½ ft. under water..... | Four inches. | ¾ pint from 1 square foot. Artificial set.... .......... |
| 26a " ...... | 1900 | Aug. 14 | 5-17 | 3,472 | .... | House-boat, 1½ ft. under water..... | " | Artificial set................ |

* Estimate

| Date of digging. | Length in millemeters. | Bulk number per quart. | Number unaccounted for. | Time between planting and digging, in weeks. | Per cent. of increase in bulk. | Per cent. of increase in bulk per week. | Remarks. |
|---|---|---|---|---|---|---|---|
| Sept. 10 | 50-70 | 36 | 86 | $20\frac{2}{7}$ | 433 | 21 per ct. | 31 alive, 75 dead shells, and many more pieces of shells. |
| May 25 | ............ | 124 | 6 | $4\frac{2}{7}$ | 55 | 11 " | |
| June 25 | ............ | 75 | 12 | $8\frac{5}{7}$ | 134 | 15 " | Preserved June 25th. |
| June 27 | ............ | 90 | 12 | $8\frac{5}{7}$ | 77 | 9 " | |
| Sept. 10 | ........... | ...... | All dead | ........ | ...... | ............ | Shells showed two months or more of growth. |
| June 10 | ............ | 90 | 22 | $4\frac{3}{7}$ | 55 | 12 per ct. | |
| Aug. 20 | 48-59 | 54 | 30 | $10\frac{1}{7}$ | 322 | 32 " | Preserved August 20th. |
| June 10 | ............ | 135 | 12 | $4\frac{3}{7}$ | 89 | 19 " | |
| Aug. 20 | ............ | 32 | 24 | $9\frac{4}{7}$ | 200 | 21 " | |
| Sept. 5 | ............ | 46 | 105 | $17\frac{6}{7}$ | 269 | 14 " | |
| Sept. 23 | ............ | ...... | .......... | ........ | ...... | ............ | Seven found alive. Were twice the length of those planted. |
| Sept. 5 | ....... .... | 50 | 137 | $17\frac{4}{7}$ | 432 | 24 per ct. | |
| Sept. 5 | ............ | ...... | .......... | ........ | ...... | ............ | One found alive. Dead shells showed increase in length of 50 per cent. |
| Sept. 5 | ............ | ...... | .......... | ........ | ...... | ............ | All dead. |
| Aug. 23 | ............ | ...... | .......... | ........ | ...... | ............ | Only three alive. |
| June 25 | 38-40 | 125 | 69 | $4\frac{4}{7}$ | 40 | 9 per ct. | Preserved June 25th. |
| June 25 | 32-41 | 140 | 70 | $4\frac{3}{7}$ | 50 | 11 " | Preserved June 25th. |
| Aug. 23 | ............ | ...... | .......... | ........ | ...... | ............ | Four found alive. Increased in length 1½. |
| Sept. 5 | ............ | ..... | .......... | ........ | ...... | ............ | Seven found alive. Increased 2½ times length. |
| Sept. 21 | ............ | 205 | .......... | 7 | 485 | 69 per ct. | Preserved. |
| Sept. 21 | ............ | 400 | .......... | 7 | 200 | 29 " | |
| Sept. 21 | ............ | 213 | .......... | $6\frac{3}{7}$ | 472 | 73 " | |
| Sept. 21 | ............ | 327 | .......... | $6\frac{3}{7}$ | 273 | 42 " | |
| Oct. 25 | ............ | 180 | .......... | $10\frac{2}{7}$ | 322 | 31 " | Sand-box had high sides. Compare growth with next experiment. |
| Oct. 25 | ............ | 108 | .......... | $10\frac{2}{7}$ | 603 | 60 " | |
| Sept. 20 | 25-44 | 177 | .......... | $5\frac{2}{7}$ | 1861 | 352 " | See page 25. |
| ........ | Average 49 | 119 | .......... | $8\frac{6}{7}$ | 1894 | 213 " | See page 25. |

*Class 1. Set of 1899 planted in beds on shore, Nos. 1–9.*—The clams were assorted according to their size, and their size is recorded in terms of the number per quart.

In the tables the column at the left shows the conditions at planting, and those at the right the results at the time of digging, with the rate of growth.

It was hoped that the difference in the rate of growth at half-tide and low-tide marks could be shown by these experiments, but the clams planted at low tide fared like those in experiment 5, *i. e.*, they were nearly all dead when examined in the summer, the empty shells, however, showing that they had lived about two months and that the mortality was sudden, although the cause is not known.

The results as they stand have some interesting features. A glance at the last column shows that the increase in bulk averaged from 9 per cent. to 32 per cent. per week. Upon comparing the dates of digging it will appear that the specimens dug up early in the season have the smaller average increase; in other words, the growth is more rapid in the latter part of the season. This may be accounted for by supposing that the clams grow faster after they spawn.

*Class 2. Planted in boxes, Nos. 10–14.*—These clams fared as badly as those planted in the beds—a sudden death carried them off after they had increased to about twice their original length. By comparing the two more successful experiments it will be noticed that the clams which were covered all the time by water increased more rapidly, a result in harmony with the conclusions arrived at the previous year, and stated in the last report, viz.: that the growth of the clam is more rapid when they are submerged a greater part of the time.

*Class 3. Wire boxes.*—The unfortunate experiments of this class speak for themselves.

*Class 4. Set of 1900 in boxes, No. 25 and 25a.*—These experiments are satisfactory and instructive. They are remarkable, also, since the boxes containing the first four experiments were of the

same kind and placed in the same locality as some of those in which other clams died earlier in the season.

Comparing the results in experiments 20–23 with one another, the average increase per week varies from 29 per cent. to 73 per cent., and the difference in growth at low tide and high tide with other conditions exactly similar is brought out in the clearest possible manner, namely, the per cent. of increase per week in the box at high tide are 29 and 42; in the box at low tide they are 69 and 73.

The next two experiments (24–25) are also very instructive. The clams in these two were from the same lot. In experiment 24 the clams were put in a small box about 18 inches deep, with a few inches of sand in the bottom, and the box was suspended near the surface of the water at the house-boat. The average increase per week is only 31 per cent. In experiment 25 the regulation shallow box was used, but was lowered 8 feet below the surface. In this box the increase was 60 per cent. per week. These two experiments, in my opinion, demonstrate two points clearly: (1) That clams will thrive at a considerable distance below the surface, if other conditions are favorable; and (2) that an apparently slight interference with the free circulation of water over the clams, like that occasioned by the high sides of the box in experiment 24, makes vast differences in the rate of growth—probably by decreasing the food supply.

Experiments 26 and 26a may be described as one, since 26a is only a continuation of the previous experiment.

These clams belong to the "artificial set" described on page 26. They were gathered from the small box on the shore, having been precipitated from the water while in the free-swimming condition. They were transferred on August 14th to a shallow sand-box suspended about a foot beneath the surface at the house-boat. The growth was more rapid than in any clams thus far described. When planted, 1,302 specimens made about three-quarters of a pint, and at this rate 3,474 would have made a quart (see Fig. 1). On September 20th the average weekly increase was 352 per cent.

The weekly average up to October 15th was somewhat diminished, being 213 per cent. The size at this date is shown in Fig. 4.

I may here once more refer to the effect of varying conditions on growth, for the box was within a few feet of experiment 24 in which the box had high sides (referred to above). But especially I would call attention to the two smaller specimens in Fig. 3, which are the same age as the larger in the group, but were left on the shore in the original box covered with a piece of wire gauze which prevented free circulation of water.

*Clams planted in land-tiles.*—In the middle of July, 1899, some specimens of the set of the previous month were planted singly in land-tiles which were set in the ground vertically, the specimens measuring from 12 to 15mm. On September 18, 1899, some of them were measured, and the growth was found to have been remarkable. The larger specimens then measured 46mm. One of these, together with a small clam of 12mm. (to show the original size in July), was photographed, and the figure is reproduced in this report (Fig. 6). Some of the tiles were left undisturbed until September 10, 1900, when three of these clams were found in them. They measured 65, 74, and 78mm., or about three inches. The largest was at the lowest level on the shore. One of these is photographed in Fig. 7 ; it is a specimen known to be one year and four months old. The surface of the shell was still covered with the skin which is usually rubbed off, and there is no line of growth, owing to the fact that the clam was not disturbed during its life of more than a year in the tile. These specimens demonstrated also as clearly as could be desired that it is necessary to dig up the soil in order that the clams may thrive.

## EXPLANATION OF FIGURES.

The following figures illustrating some of the new experiments on the rate of growth are reproductions of life-size photographs of species which have been preserved in the same order as they are arranged in the figures, and can thus be referred to any time.

### Plate I.

Fig. 1. Clams of "Artificial Set" caught from swimming larvæ (page 26). Dug and preserved, August 14, 1900.

Fig. 2. Clams of "Artificial Set" reared in sand-box August 14 to September 8, at house-boat (page 43).

PLATE I.

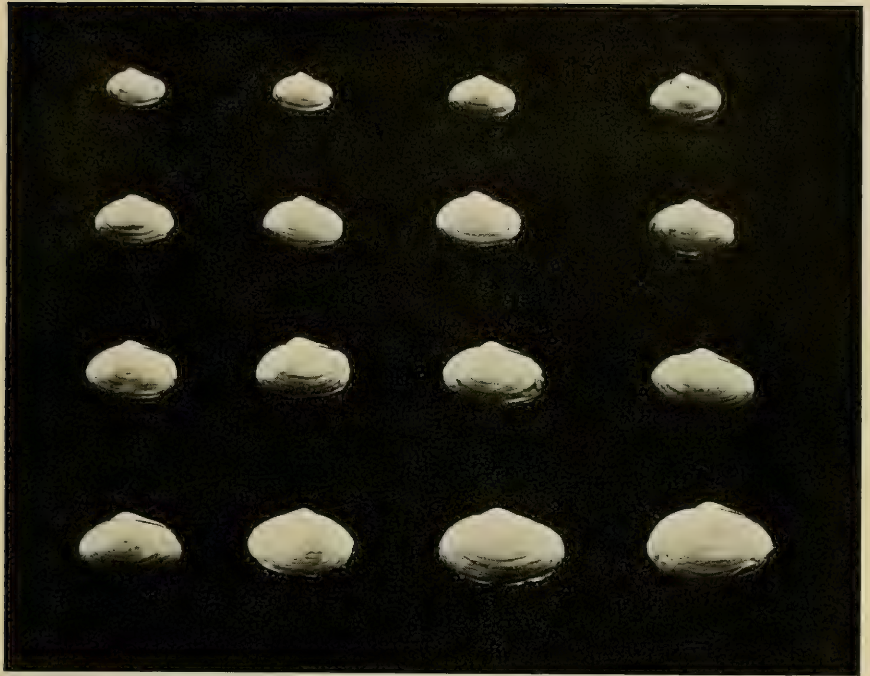

FIG. 1.

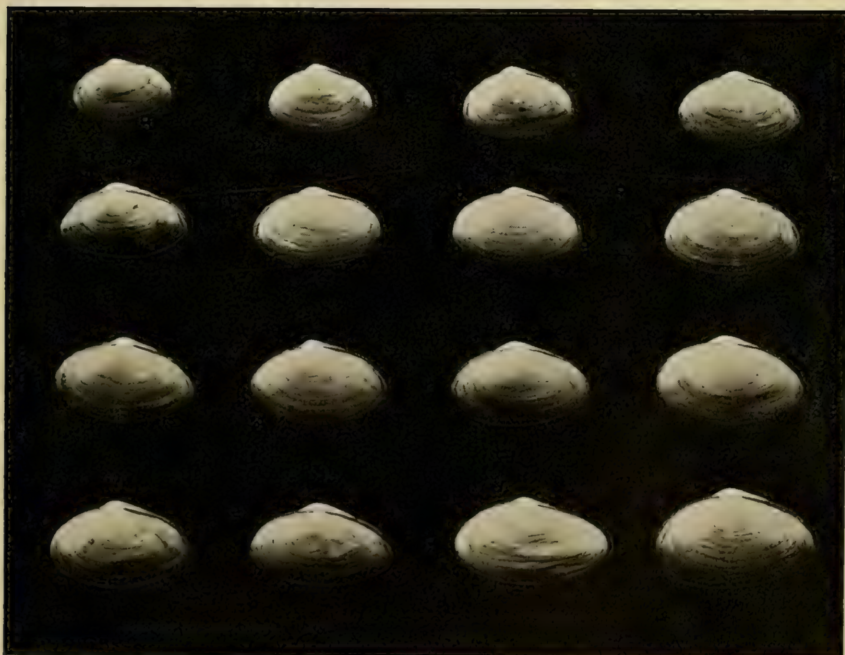

FIG. 2.

## Plate II.

Fig. 3. The large specimens are clams of "Artificial Set" reared from August 14 to September 20, in sand-box at house-boat. Two smaller specimens: "Artificial Set" left from August 14 to September 20 in the original box on shore, and covered with wire gauze (page 43).

Fig. 4. Clams of "Artificial Set" reared from August 14 to October 15, in the sand-box at house-boat. The two specimens on the upper row, and the left-hand one in the middle row, show the lines of growth resulting from slightly filing the edge of the shell on September 20 (page 44).

Plate II.

Fig. 3.

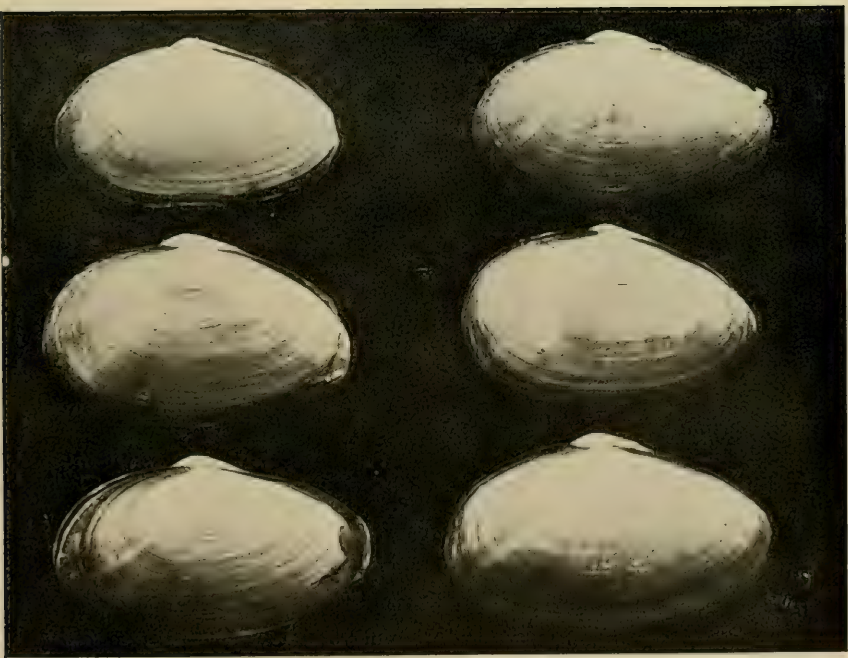

Fig. 4.

## Plate III.

Fig. 5. The larger specimen was taken September 18, 1899, from a land-tile set in the mud on the shore (Wickford) at low-water mark. It was placed in the land-tile on July 22, 1899, when it was the size of the smaller specimen. The difference in size represents two months' growth (page 44).

Fig. 6. One of the land-tile specimens planted July 18, 1899, when of the size of the smaller specimen in Fig. 5, and dug on September 10, 1900 (page 44). It is, therefore, about a year and three months old.

Plate III.

Fig. 5.

Fig. 6.

Plate IV.

Fig. 7. Specimen of the fall (3) set of 1899 taken in April, 1900. (They show the small corroded piece of the shell next the hinge which represents an old growth. The greater part of the shell is new growth (page 23).

PLATE IV.

FIG. 7.

## IX. Continued Work on Off-shore Fisheries.

The U. S. schooner "Grampus" visited the tile-fish grounds again this year and brought in a large quantity of tile-fish, which were distributed in the markets of the principal cities of the east. The fish is now becoming favorably known among consumers.

## X. An Investigation of the Habits and Life-History of the Scallop.

The scallop-fishing in Rhode Island is in imminent peril, and every one who is acquainted with its history knows that unless the industry is protected by effective legislation it will become defunct. No one appreciates this more keenly than the scallop fishermen themselves; that they do not protect the scallops is not strange, for the law is not sufficiently explicit, nor the enforcement as efficient even as it might be.

The immediate reason for undertaking study of the life-history and habits of the scallop was to gather information, by inquiry, observation, and experiment, which would afford a scientific basis for effective legislation.

The investigation was intrusted to Mr. Jonathan Risser, A. M., of Brown University, under the direction of Dr. A. D. Mead.

# HABITS AND LIFE-HISTORY OF THE SCALLOP

(*PECTEN IRRADIANS.*)

## PRELIMINARY REPORT.

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The conditions of the occurrence of scallops at Wickford, R. I., during the last few years affords an unusually favorable opportunity for solving the problems of the growth and breeding-habits of this shell-fish. In the spring of 1899 there were practically no scallops in the vicinity of Wickford, but in the summer of the same year an abundant set of young scallops made its appearance. This fact has simplified the problem of following the development of a certain set because it obviates the possibility of confusing the set of two successive spawning-seasons. The record of the observations which have so far been made will be given in answer to the following questions:

1. When is the breeding-season of the scallop?
2. What are the breeding-habits?
3. Can the eggs be artifically fertilized?
4. What are the habits of the fry?
5. What are the habits of the young scallops after they have set?
6. What is the rate of growth?
7. At what size and age does the scallop first spawn?
8. Does the scallop spawn more than once?
9. What is the normal length of life?

1. *When is the breeding-season of the scallop?*—In order to make sure of the time of breeding, the scallops of the set of 1899 (the only set then present at Wickford) were examined at intervals through the winter and spring of 1900, and the condition of the developing eggs and spermatozoa were observed. By the middle of May all the specimens were apparently nearly ready to spawn.

On the 8th of June several specimens which were being kept in aquaria at the house-boat extruded their eggs in great quantities, and from this time until July they continued to spawn. It is difficult to fix the exact limits of the breeding-season, but it begins about the first of June and reaches its height about the middle of the month. In July nearly all the specimens had discharged their eggs.

It would be a fair statement to say that the scallops spawn in June.

2. *What are the breeding-habits?*—The scallop differs in one striking particular from our other edible shell-fish, the clam and the oyster. It is an hermaphrodite, the eggs and spermatozoa being developed in the same individual, while in the clam and oyster the sexes are separate. If the scallop be opened in May, when it is sexually ripe, a bright orange-colored mass will be observed; this is made up of an immense number of eggs packed closely together. The spermatozoa lie in a whitish mass near this place, but do not occupy so much space. The eggs are extruded into the water as in the case of the clam and oyster, there to be fertilized by sperm, for the most part probably from other individuals. However, in the aquarium on some occasions, when a single specimen was kept by itself, eggs were laid and fertilized by the sperm of the same individual. A few of them developed for a time, but not so well as in other cases; whether this was due to the self-fertilization or not is a question not definitely settled.

By watching the spawning of the animals it was observed that they extruded their eggs, not little by little through several days, but the whole mass, probably more than a million in number, were discharged in the course of an hour and a half.

## PHOTOGRAPHS.—LIFE SIZE.

PLATE I. Set of 1900, Greenwich Bay. Upper two rows taken between August 1st and August 15th. Lower three rows, specimens taken between August 15th and September 1st.

Plate I.

Plate II. Set of 1900, Greenwich Bay. Upper two rows show average size in September. Average on September 10th, 25mm. Average on September 24th, 29.5mm. The two shells in the lower row at the right were kept in the car from September 10th to October 13th. Third row, average size for October under natural conditions, 34.56mm. Fourth row. Shells kept in car on house-boat from September 10th to October 16th.

Plate III. Set of 1899, Wickford. The average size on October 2d, 1899, was 42.5mm.

PLATE IV. Set of 1899, Wickford. Average on December 4th, 1899, 44.35mm. Taken on shore.

PLATE V. Set of 1899, Wickford. These were taken from the deep water in the channel January 11th, 1900. Average of lot, 55mm.

Plate VI. Set of 1899, Wickford. Taken from the deep water in the channel March 20, 1900. Average, 56.8mm.

PLATE VII. Set of 1899, Wickford. Taken from the deep water in the channel April 21, 1900. Average, 58.3mm.

Plate VII.

Plate VIII. Set of 1899, Wickford. Taken in shallow water May 30th, 1900. Average, 60.7mm. Very little growth has been evident in the months since January.

Plate IX. Set of 1899, Wickford. Specimens taken between July 1st and July 12th, 1900, from shallow water. Average, July 1st, 1900, 60.5mm. These all show the "line of growth," which only made its appearance at the time of spawning. After spawning the growth of the shell goes on rapidly.

PLATE IX.

PLATE X. Set of 1899, Wickford. August 1, 1900. Specimens taken from channel. Average of lot measured 62.75mm. A large increase of growth is shown at this time.

PLATE X.

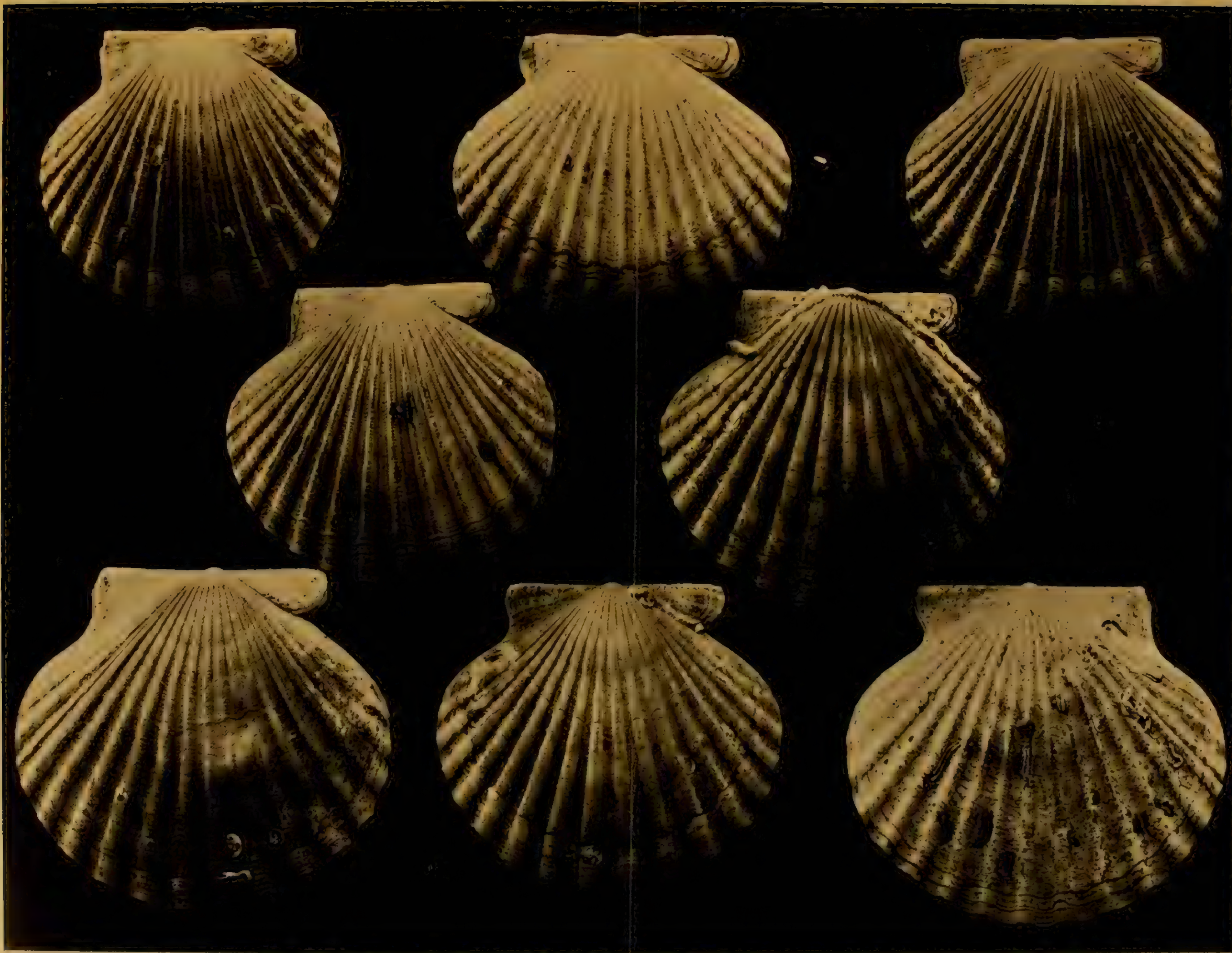


Plate XI. Set of 1899, Wickford. Taken September 18th, 1900, from channel. Average, 71.6mm. Growth has gone on rapidly during August and September.

PLATE XI.

Plate XII. Set of 1899, Wickford. Taken October 16th, 1900. Average, 79mm. Growth has gone on rapidly during the warm months.

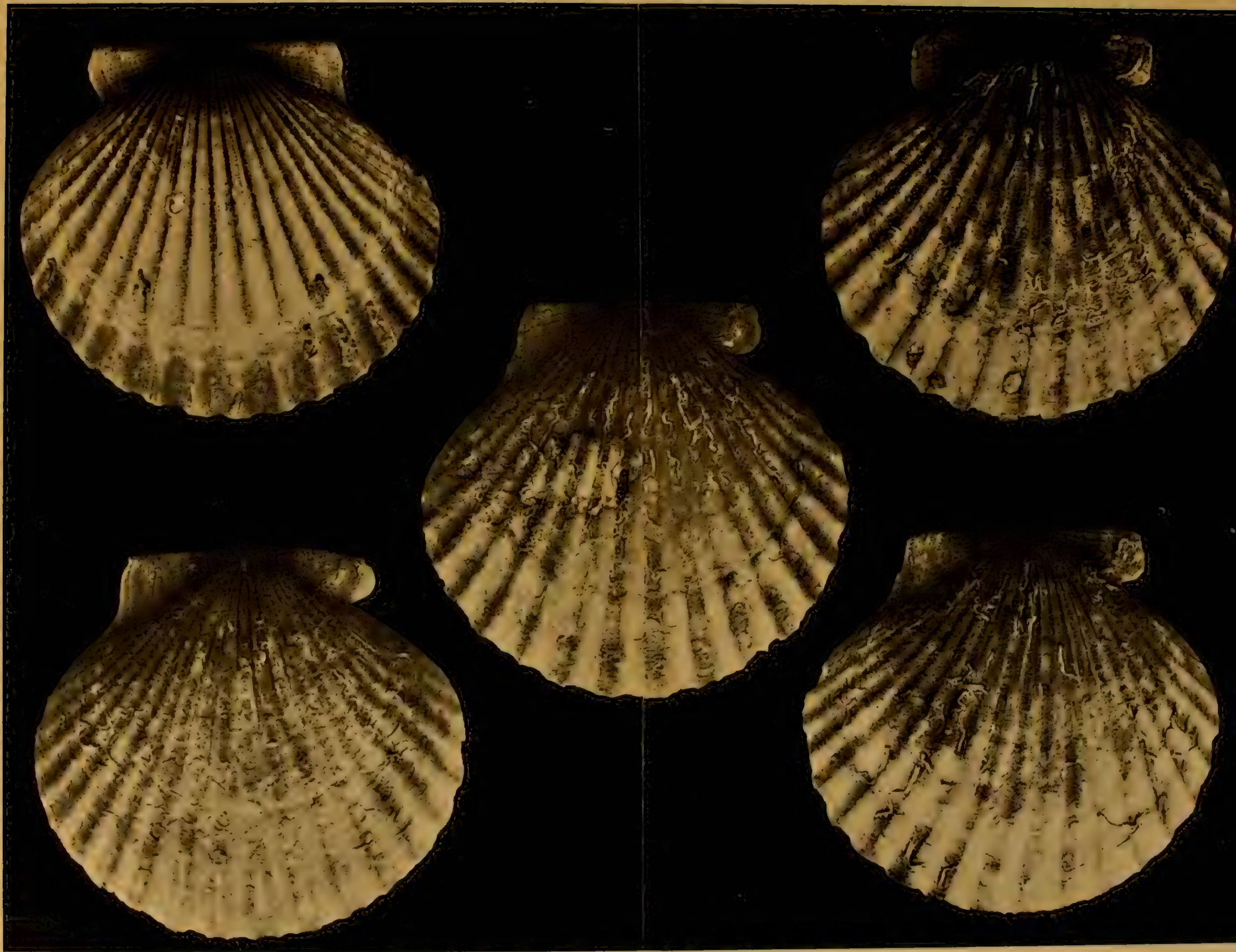


PLATE XIII. Set of 1899, Wickford. Taken November 6th, 1900. Average, 81mm. Note the "line of growth" and its relation to the free edge of the shell. Compare with sets of July and August.

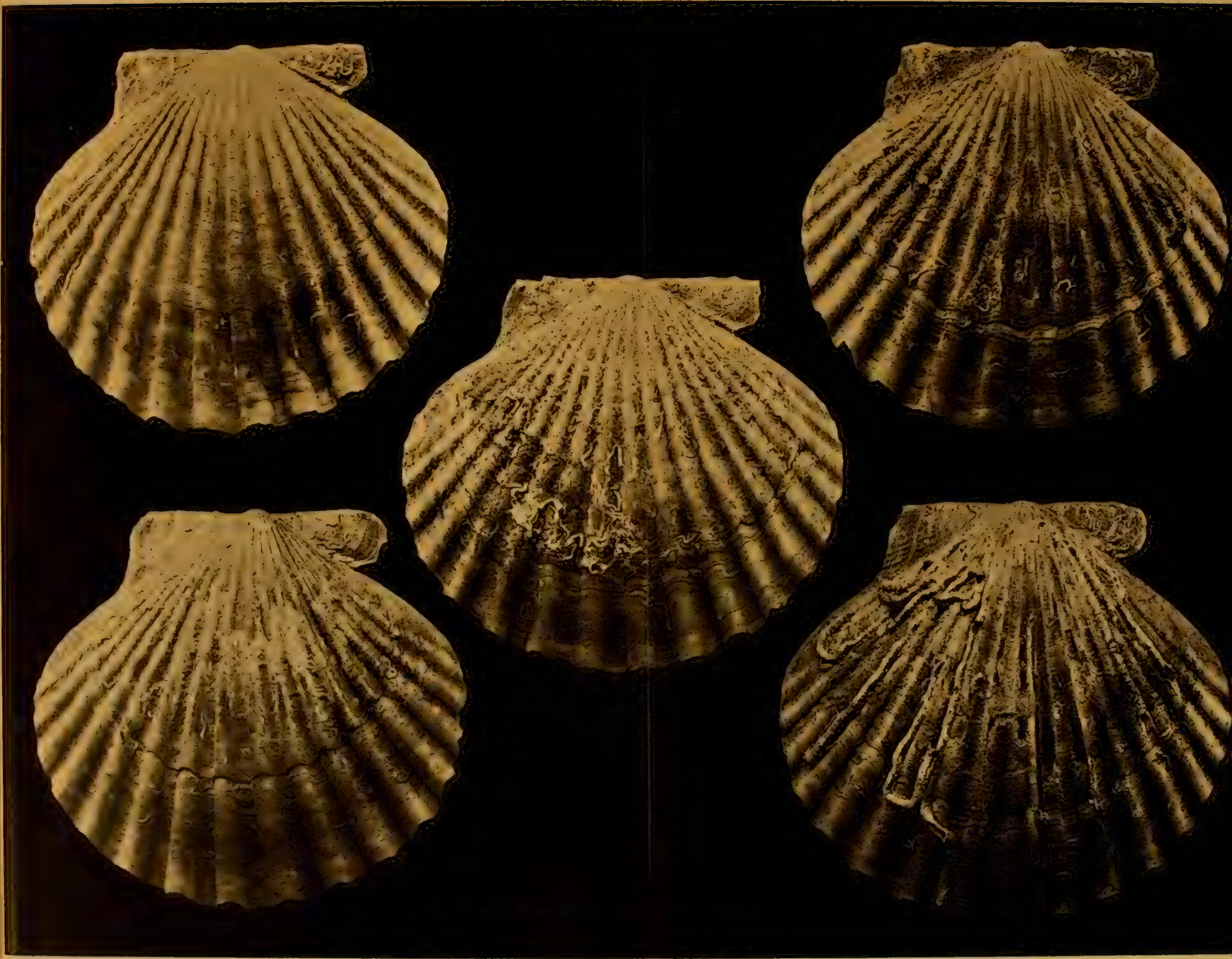
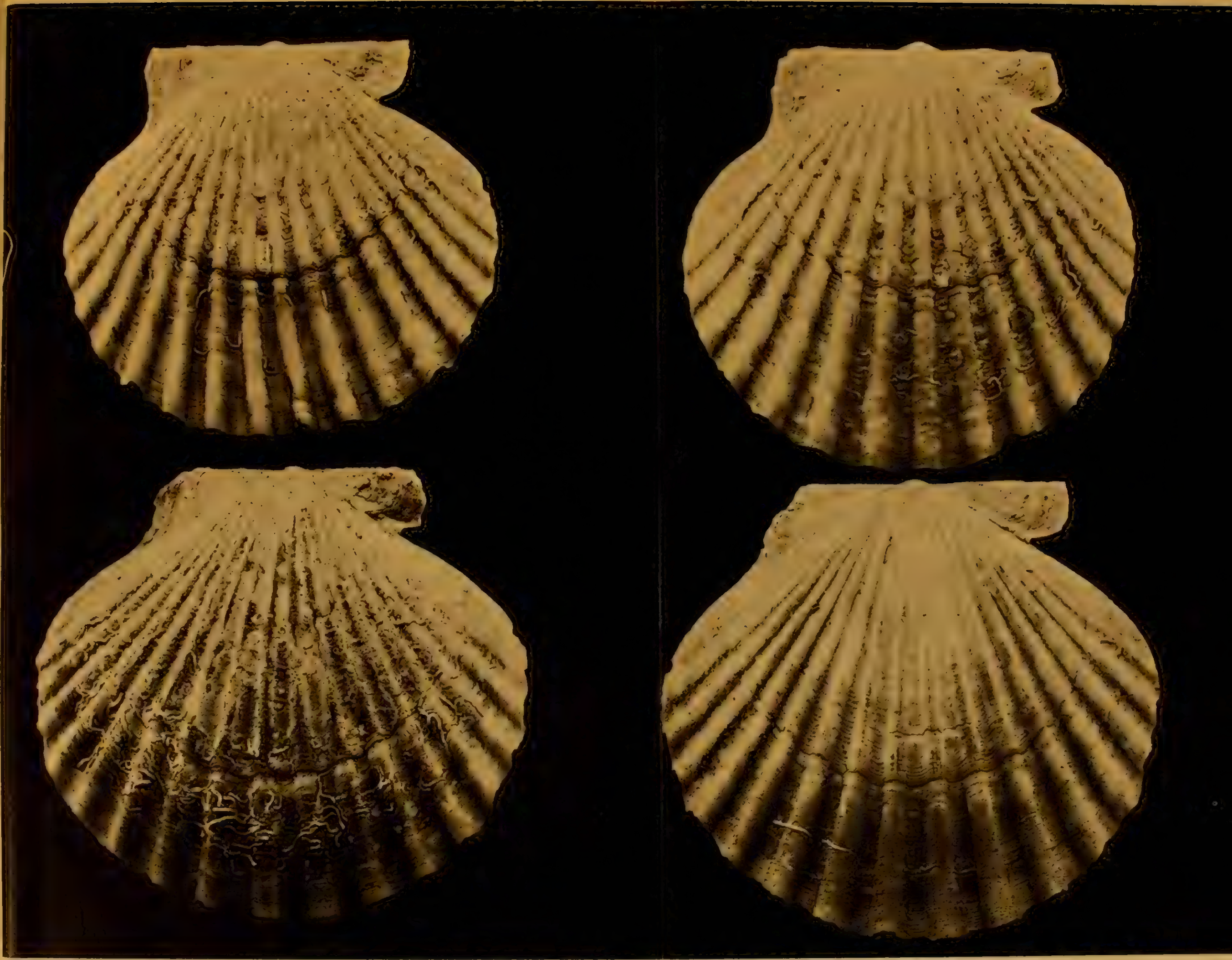


Plate XIV. Set of 1899, Wickford. Taken December 3d, 1900. Average, 86.8mm. Growth has still been going on during November. At this date the specimens were very uniform in their dimensions.

Plate XV. Set of 1899, Wickford. Taken January 11th, 1901. Average, 84mm. In the lot taken at this time were many below the normal. This reduces the average somewhat. Some measured as much as 97mm.



3. *Can the eggs be fertilized artificially?*—From the 8th of June to the end of the month it was possible to obtain eggs and sperm from the scallop and fertilize the eggs artificially. It was discovered, after several experiments in dissecting the animals to obtain the eggs, that if the ripe scallops were allowed to remain for a few days after being collected they would of their own accord discharge the eggs and sperm. The eggs were, as a rule, discharged at a different time from the sperm, and, therefore, by keeping the individuals in separate dishes, the eggs could be obtained unfertilized before the sperm was extruded. In this way they could, of course, be fertilized at any particular moment which was desired.

4. *What are the habits of the young fry?*—In the appearance of the eggs and the characteristics of the early stages the scallops bear a close resemblance to the clam and oyster. The eggs are spherical and very small, about $\frac{1}{6000}$ inch in diameter. They are fertilized in the sea-water and then immediately commence the series of internal changes which result in successive alterations in structure and in external form of the microscopic fry.

From the experiments in artificial fertilization, material was furnished in abundance for the study of the stages heretofore unknown in the case of the scallop. An account of the details of the development will not be given here, but only some of the general features.

During the first 12 hours after fertilization the eggs lie motionless on the bottom. At the end of this period they commence to rotate slowly at first, but with increasing rapidity. By the time they are 36 hours old they swim with considerable rapidity, and are constantly in motion. There is no increase in size from the time the eggs are fertilized to the time they begin to swim. Growth begins soon after this, however, and in the following days of ceaseless activity the minute creatures are swimming in quest of food. Throughout the free-swimming period they are like the larvæ of other forms in being very sensitive to light, and are attracted or repelled by it according to various circumstances. By

the time they are 48 hours old the shells are formed with a shape characteristic of the scallops and distinguishing them from other shell-fish in the corresponding stages of development.

How long the scallop remains in the swimming stage is not known. There are obvious difficulties in the way of confining such minute and active creatures, and at the same time giving them a free circulation of water.

They were kept for four days, however, in the swimming condition, and it is hoped that during the next summer the duration of the free-swimming period may be ascertained.

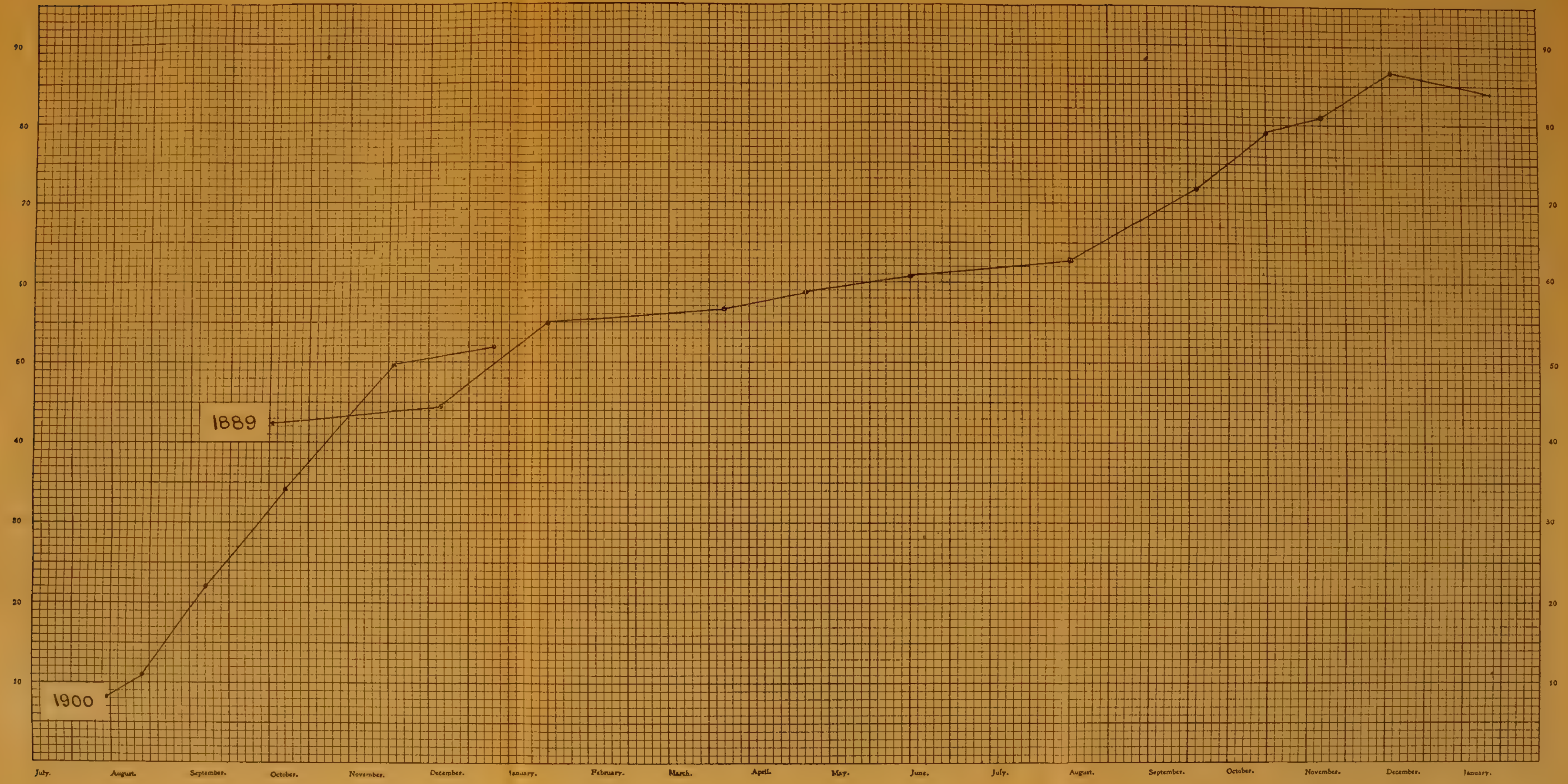
5. *What are the habits of the young scallops after they have set?* —The actual changes undergone when the swimming "larvæ" sets and becomes attached to the eel-grass, sea-weed, etc., awaits investigation. The setting doubtless occurs from June 1 to July 1, when the young are still of microscopic size. Throughout August and even in September the newly set scallops may be found in the eel-grass attached to the grass or sea-weed by byssus threads like those which are spun by the mussels and the young of the soft clam.

6. *What is the rate of growth under natural conditions?*—This problem has received a good share of attention because of its economic as well as biological interest, and also because the opportunities for solving it were, at Wickford, exceptionally favorable. The systematic observations on the rate of growth were begun in October, 1899, on the set of the previous June, and have been continued up to January, 1900. The record, therefore, covers the period from the 4th to the 18th month of the life of the 1899 scallops.

The method employed is as follows. A large number (200–1,000) of specimens were taken at intervals, usually of about a month, and carefully measured with calipers, and the average size obtained for each date.

This method is satisfactory and gives a faithful record of the growth because there is only a comparatively slight variation in the size of the individuals of the same set at any one time. For in-

CHART showing curve of *Rate of Growth* of *set* of 1899, from October, 1899, to January, 1901, from *Wickford*, comparing with it growth curve of *set* of 1900, from Greenwich Bay, from August 1 to December, 1900.



stance, in the 200 measurements taken on Dec. 4, 1899, the extreme sizes were 36mm. and 56mm. This uniformity of size among the scallops may be accounted for by the fact that the breeding-season is short, and that the conditions of obtaining food are less variable than for many species.

The following is a list of the average length of the specimens on the various dates, with references to the plates illustrating the size and appearance of the scallop. The figures are from life-size photographs in every instance:

*1899 Set, Wickford.*

| | | | | |
|---|---|---|---|---|
| October | 2, 1899 | ........42 | mm........ | Plate III. |
| December | 4, " | ........44.5 | " ........ | " IV. |
| January | 11, 1900 | ........55 | " ........ | " V. |
| March | 20, " | ........56.8 | " ........ | " VI. |
| April | 21, " | ........53.3 | " ........ | " VII. |
| May | 30, " | ........60+ | " ........ | " VIII. |
| July | 1, " | ........60+ | " ........ | " IX. |
| August | 1, " | ........62.75 | " ........ | " X. |
| September | 18, " | ........71.6 | " ........ | " XI. |
| October | 16, " | ........79 | " ........ | " XII. |
| November | 16, " | ........81 | " ........ | " XIII. |
| December | 3, " | ........86 | " ........ | " XIV. |
| January | 11, 1901 | ........85 | " ........ | " XV. |

The interesting features of this record of growth can be pointed out more readily by reference to the curve plotted in the accompanying diagram. In the curve the heavy dots indicate the date of measurement and the average size taken from the preceding table, *i. e.*, the vertical distance of any dot represents the size of the scallops in millimeters as indicated by the scale on the side, while the horizontal distance of this dot from the left side represents the age of the scallop as indicated by the scale on the bottom line. By connecting the dots with a line we have a curve which represents graphically the rate of growth.

Where the curve is steep, the growth is rapid; where it is on the level, there is no growth.

It will appear at once from the curve that the growth continued rapidly through the fall and early winter, *i. e.*, between October 2d and January 11th.

After the January measurement the growth becomes slow and continues slow until the first of August. This is the period of the growth that is of particular interest, for the slow growth continues not only through the cold months from January to April, but through May, June (June being the month of least growth), and a part of July. In August the rapid growth begins again and continues, in the warm and cold months alike, up to December.

It is evident, therefore, that the temperature of the water does not to any very great extent determine the rate of growth of the scallop.

*Cessation of growth and its relation to the breeding-season.*—It has already been stated (p. 48) that the sexual products develop in the body of the scallop during the winter and spring. In May the glands are distended with eggs, and in June nearly all the eggs are laid. There is, therefore, a striking correspondence between the slow growth from January to July and the development of the sexual products. *As soon as the spawning-season is past the rapid growth begins again.*

*Line of growth.*—In old scallops there is a plainly marked line running across the shell, parallel with the margin, which is called the line of growth, and upon it the fishermen base their judgment of the age of the scallop. What is the explanation of this line, and what does it signify? It has been shown in the case of the clam that the similar lines of growth do not indicate the age of the individual, but are due to the accidents in the life of the clam when the margin of the shell is injured—as by burrowing in gravel. Clams, therefore, which are frequently disturbed have numerous lines of growth, while those left undisturbed, like the one photographed in Fig. 6, show none. In the scallop the case is different. The usual opinion is that the line marks the cessa-

tion of growth in the winter—due to the cold weather. The observations on the set of 1899 show clearly that the line is constant in every specimen and marks the cessation of growth—not however in winter, but in mid-summer. The margin of the shell is doubtless already subjected to more or less wear, but so long as the growth is continuous no heavy line is developed. In June, during the spawning-season, as is shown on the chart, there is no growth for a comparatively long period, and it is this period of rest which accounts for the "line of growth." The series of figures representing scallops taken throughout the year demonstrates this. (Plates III–XV.)

This conclusion is, of course, founded upon only one year of observation, but is in all probability correct, and in any case will be checked by the observation on the set of 1900.

The observations on the rate of growth and the meaning of the line are of more than passing interest, for they demonstrate clearly that it is possible to tell whether a scallop is more or less than one year old. Except in respect to the time when the line appears, the results accord entirely with the information received from fishermen.

*Growth of the set, 1900.*—The rate of growth of last season's scallops is being observed at Greenwich Bay. The record extends from August to December, and is plotted in curve opposite page 50.

The sample specimens taken during (a) the first of August, (b) the last of August, (c) September, and (d) the first of October are photographed natural size in plates I and II.

The following is the average size of the sets of 1900 in October, November, and December:

| | |
|---|---|
| October 6 | 43.56mm. |
| November 19 | 49.81 " |
| December 24 | 52.12 " |

The relative size for sets of 1899 and 1900 at various dates can be seen at once by referring to the curves.

7. *At what size and age does the scallop spawn?*—So far as the age is concerned, the question can be answered with precision and brevity: The scallop spawns when one year old. The size probably varies from year to year with certain limits, but for the set of 1899 the average size was 60mm. or about 2½ inches from hinge to ventral margin.

8. *Do they spawn more than once?*—The scallopers are practically unanimous in the opinion that the animals spawn only once, and they are probably, in the main, correct. For the set of 1899 this question cannot be answered definitely until next summer. It has been observed, however, that some of the specimens in January of the second year were developing eggs and spermatozoa again.

9. *What is the normal length of life of the scallop?*—The general opinion on this question is probably correct, namely, that the scallop normally lives not more than two years. No very definite information could be obtained from inquiry in regard to the exact period of termination of life. Obviously this question must also be deferred to another season.

In conclusion we may bring together some of the facts recorded above and point out their relation to one another and their bearing upon the welfare of the scallop industry in the waters of the State.

1. The injury to the industry by the practice of taking scallops less than a year old is very grave, for several reasons:

(*a*) The number destroyed in obtaining a given quantity of meat is, of course, much greater than necessary.

(*b*) The destruction of the young lessens the number of spawning scallops for the following summer.

(*c*) Moreover, the young scallops are the *only* source of the next year's supply if it is true that they breed only at the end of their first year; whereas, in the case of the clam and other food animals, the adults breed for several seasons.

(*d*) The scallops of more than a year's growth can be taken without any effect on the subsequent supply.

(*c*) The distribution of the scallop is of a local nature, and our waters are not replenished by a general supply from outside the Bay as in the case of many fishes. The industry depends, therefore, on the treatment given the scallop within our own State.

2. The requisite knowledge is at hand for distinguishing readily the scallops of more than a year's growth from those which are less than a year old and have not spawned, and, therefore, no reasonable excuse exists for taking the young:

(*a*) The set of scallops belonging to the set of any year are of nearly uniform size, owing to the brevity and definiteness of the breeding-season.

(*b*) Besides the evident difference in size of scallops of two consecutive years, the scallops which have spawned are marked with the "line of growth," and those which have not spawned are not so marked.

## XI. Further Observations on the Red-Water Plague, with Notes on its Occurrence Elsewhere.

This phenomenon, which has been noticed for years by fishermen in the upper part of the Bay, was so unpleasantly noticeable in the late summer of 1898 that it caused a great deal of comment. In the report of that year your commission, having investigated the matter, published a brief statement of the cause of the red color and the disagreeable odor of the water.

The explanation of the red water is the exceeding abundance of a minute organism, called at that time *Peridinium*. Specimens were sent to Sir George Murray, of England, who was engaged in a work on the *Peridinidæ* of the world, and were pronounced by him to be a species of the related genus *Gymnodinium*. The species itself was unknown to him, and, in his opinion, probably new.

In 1899, and again in this year, the red water has recurred. On May 6th the Lewis Brothers saw large patches of it between Wickford Light and Plum Beach. The organisms were abundant in the skimmings for some time after this. In the early autumn, particularly about the last of September and the first of October, it again amounted to a plague in the Providence River. Crabs, shrimp, menhaden, clams, and various other animals were found piled in windrows on the shore, while squiteague of from 1 to 2 inches in length were to be seen stupefied and half dead in the shoal water.

On Octobter 18th the shore north of the harbor near the R. I. Yacht Club house, was covered with a broad windrow of clams for nearly a quarter of a mile. At many places the clams were piled a foot in height, and the total amount thus killed must have amounted to many thousands of bushels. The clams were evidently of this year's set for the most part, and measured about $1\frac{1}{2}$ inches in length. Many were not dead, and very few had been dead many days. It can not be stated positively that the red

water was the cause of this destruction, but it appears extremely probable.

It is desirable that a further careful study be made of the life-history of the organism, and of its actual destructiveness.

Similar phenomena have been observed in Japanese waters, and specimens of the organism which caused the coloration of the water have been sent to your commission for comparison with the species found here.

## XII. Additions to the List of Fishes Known to Inhabit Narragansett Bay, with Remarks on Rare Specimens Recently Caught.

*Pteroplatea maclura* (Le Sueur). "Butterfly Ray;" "Angel Fish."

Although the type specimen of this species was taken in Rhode Island in 1817 and described by Le Sueur, it has not been previously reported by the commission. A specimen 23 inches long was taken in the southern part of Narragansett Bay, during July of this year, by the Lewis Brothers. Long Island Sound is usually considered to be the limit of its northern range, but Mr. Lewis says that it is found not infrequently in the Bay. This specimen is preserved among the collection of Rhode Island fishes belonging to the commission.

*Tarpon atlanticus* (Cuvier and Valenciennes). "Tarpon;" "Tarpum."

Mr. H. M. Knowles, of Wakefield, R. I., is authority for the statement that a tarpon 5 feet long, and so slender that it weighed only 30 pounds, was taken in a fish-trap near Dutch Island Harbor. This catch was noted in the Providence Journal of July 25, and the fish was exhibited at Narragansett Pier. A few are taken in this vicinity every year, but as their flesh is dry and tasteless they have very little food value. A specimen weighing

80 pounds was taken at Martha's Vineyard, and a small one was caught in the U. S. F. C. trap at Wood's Hole.

Other common names for the tarpon are Grand Écaille; Silver-fish; Sabalo; Savanilla; Savalle. The average length for the species is 6 feet, and the maximum weight is 110 pounds. Narragansett Bay is probably its northern limit of range, but probably it does not breed north of Cuba. Stearns says of it: "An immense and active fish, preying on schools of smaller fry, in pursuit of which it ascends fresh water rivers quite a long distance." An excellent specimen is preserved in the collection of the Rhode Island Fishes.

*Trachiurus lepturus* (Linnæus). "Cutlas Fish;" "Scabbard Fish."

An unusually large specimen, measuring 3 feet, 8 inches, was taken in a trap at Newport. This species is abundant in tropical seas. The northern limit of range is given as Virginia, although they are occasionally taken farther north. The largest specimen hitherto recorded from New England waters was caught at Wood's Hole in 1874, and measured 3 feet in length. Other common names are: Silver Fish; Sable; Savola.

*Lobotes surinamensis* (Bloch). "Flasher;" "Triple Tail."

A specimen of *Lobotes* weighing nearly 6 pounds and measuring 22 inches, was taken in Mr. Kaye's trap off Pine Hill, Prudence Island, on September 10, 1900. This inhabitant of all tropical seas is a very rare visitor in Rhode Island waters. Not more than six specimens have been recorded from this vicinity in the last thirty years. It is sluggish in its habits, but valuable as a food fish.

*Lagocephalus lævigatus* (Linnæus). "Smooth Puffer."

Three specimens of this occasional visitor have been recorded for this year. The largest, weighing 10 pounds, was taken at Tiverton, October 4, by R. B. Wilcox. Another smaller specimen was

collected by J. M. K. Southwick, at Newport, September 29. Its natural range is from Cape Cod to Brazil. They are common in the south, but are very rare north of Cape Hatteras. Since their flesh is ill-flavored and said to be poisonous, they are not valuable as food. The average length is 2 feet. One somewhat smaller was caught in a purse-net near Point Judith by Joseph Church, September 28.

*Hippoglossus hippoglossus* (Linnæus). "Halibut."

On April 16 a 100-pound halibut was brought to Newport. It was caught with others off Block Island by a cod fisherman. Halibut were formerly quite common around Block Island and Vineyard Sound, but none have been taken for several years. The catch leads one to hope that this valuable food fish is again returning to our waters.

The halibut is the largest of the flounders. Its maximum weight is about 400 pounds, and it is one of our most important food fishes. It is found on all the cod banks of our northern seas, and ranges as far south in the West Atlantic as Sandy Hook.

## XIII. Experiments in Lobster-Culture.

The artificial hatching of lobster eggs has been carried on for many years at the U. S. F. C. stations at Wood's Hole and Gloucester, and the young fry turned out each year in immense numbers. Within a day or two after they have been hatched the young lobsters are taken in jars, carried out into the sea, and are then put overboard. It is admitted that the procedure is unsatisfactory, from the fact that the fry are poorly equipped to take care of themselves at this early stage. The reason for turning them loose, however, is that they would die if kept in confinement.

Many attempts have been made, both abroad and in this country, to rear the newly-hatched lobsters; within the past two years the United States Fish Commission has given to this problem special attention, and a series of experiments have been instituted

in various localities under the direction of Dr. H. C. Bumpus, Director of the Biological Station at Wood's Hole and member of your commission. The record of the progress of the first year of investigation was embodied in the last report (page 42).

On the first of June of the present year the first lot of newly-hatched lobsters was brought from Wood's Hole to Wickford, and throughout the rest of the season the Wickford Station co-operated with the United States Fish Commission in their experiments. Eleven importations of lobster fry were brought to Wickford during June and the first of July, and the results obtained here were more satisfactory than in any other locality in which the experiments were conducted.

The following is a report on the progress made in lobster-culture at the Wickford Station :

# HABITS AND GROWTH OF YOUNG LOBSTERS

AND

# EXPERIMENTS IN LOBSTER-CULTURE.

A. D. MEAD, PH. D.,

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The investigations here recorded were made during the past year at the new floating laboratory of the R. I. Commission of Inland Fisheries, located in Mill Cove at Wickford. They were undertaken in conjunction with the U. S. Fish Commission, which furnished an abundance of newly hatched fry and much of the requisite apparatus for the work.

The main purpose of the work this year was, first, to ascertain the habits and rate of growth of the young lobsters from the time they were hatched until they had moulted three times and reached the fourth stage of development; and, second, to invent means for rearing them through these stages of development. Desultory observations of considerable interest were made, however, upon the later stages.

The critical nature of the early period of life was more than ever emphasized by these observations. During the first three stages the young are small and delicate and are especially exposed, since they swim constantly near the surface of the water or, what is worse, lie helpless on the bottom. They, moreover, lack both the ability to move quickly and the instinct to escape their very numerous enemies. Immediately on reaching the fourth stage

their structure and habits are remarkably altered; they are larger, stronger, exceedingly active, and at once seek hiding-places under stones, shells, etc., or actually burrow in the sand.

In the study of these stages several problems are presented:

### Habits and Growth.

1. What changes in structure occur in the early development?
2. What is the duration of the first three stages?
3. What are the general habits of life in the first four stages?

### Experiments in Lobster-Culture.

4. What is the best method of supplying food?
5. What is the best means of protecting the fry in the first three stages?

The solution of these problems would mean a great advance in the efficiency of general propagation of lobsters, and would be the first step toward artificial lobster-culture.

1. *What changes in structure occur during the early development?*—An excellent account of the structural changes from the egg to fourth moult is to be found in F. H. Herrick's monograph of the lobster,* and it will hardly be necessary to describe these in detail in this place. The general appearance, size, etc., of the various stages are, however, illustrated in the photographs (Figs. 5–8), and the drawings (Figs. 1–4) made after Herrick's figures. These will give a more definite idea of the structural peculiarities in the different stages. But a true appreciation of these interesting youngsters can be had only by observing the beautiful coloring and droll antics of the creatures in life.

Besides the difference in size there are certain other characteristics which distinguish the various stages. In the first three stages the body is always strongly bent, while in the fourth it is usually straight. In each stage the large claws are carried in a peculiar manner. At first they lie nearly parallel to the side of

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* F. H. Herrick, "The American Lobster," Bulletin of the U. S. Fish Commission for 1895.

the body and point backward, but in each succeeding stage they tend to point further forward, so that in the fourth stage, when the animal swims, the big claws meet in front of the head. The surest and quickest means of distinguishing them is, however, by the appendages on the underside of the abdomen (tail). In the first stage there are none. In the second stage the several pairs of swimmerets are developed (Fig. 2). In the third stage the appendages on the segment at the tail end appear (Fig. 3). The fourth stage is so different from the previous ones that no difficulty is ever experienced in detecting it.

2. *What is the duration of the first three stages?*—The average period between hatching and reaching the fourth stage for the entire eleven experiments at Wickford was a little over twelve days. In each experiment the average duration of the first three stages, meaning the interval between the time of hatching and the day upon which the *largest number* entered the fourth stage, is given in the table on page 78, and varies from nine to sixteen days. From the first experiments, begun June 1, to the later ones there is a variation in the length of the period among different individuals, amounting to three or four days at the least, and in some instances even to six or seven days.

In experiments conducted at Wood's Hole the time required for these moults was considerably greater; of the first lot, hatched May 23d, the first stage was reached by a few only on June 12th, after an interval of twenty days. Indeed, on the twelfth day (the average time of reaching the fourth stage at Wickford) none had reached even the third stage at Wood's Hole. The explanation of the variations in the length of time required for the first three stages probably lies in the differences in temperature of the water—the colder the water, the slower the development. An examination of the tables referred to bears out this conjecture, thus:

| | | | Average temperature. |
|---|---|---|---|
| Experiment | 1. | Duration of first three stages, 16 days. | 65° F. |
| " | 2. | " " " 15 " | 66° F. |
| " | 3. | " " " 13 " | 68° F. |
| " | 4. | " " " 13 " | 68° F. |
| " | 5. | " " " 13 " | 69° F. |
| " | 6. | " " " 10 " | 70° F. |
| " | 7. | " " " 12 " | 72° F. |
| " | 8. | " " " 12 " | 72° F. |
| " | 9. | " " " 10 " | 72° F. |
| " | 10. | " " " 9 " | 72° F. |
| " | 11. | " " " 11 " | 73° F. |

It is not possible to say at present that the variations in the length of the early stages are due entirely to the difference in temperature, and it may be that other factors have more or less influence; but it is extremely probable that temperature is the main factor. In other animals the increase of temperature is known to have an accelerating effect on the development, *e. g.*, in the development of the eggs of one of the marine worms, *Lepidonotus*, the development could be increased to three times its usual rate by warming the water.

The proportion of time spent in the first, second, and third stages was, at Wickford, approximately equal (see table, page 78), but the record is not complete enough to allow very accurate statements as to the exact amount of time spent in each stage.

From the standpoint of lobster-culture there are advantages in making the duration of the critical period as short as possible, besides the saving of extra labor. The especial dangers to which the young are exposed from their enemies and from physical environment are materially increased when the fry develop slowly, so that the sooner they reach the fourth stage the less they need be exposed. Among the enemies must be recorded in this connection the vegetable growths of various kinds which find

lodgment on the young lobster. Diatoms, fungi, and even green algæ, grow upon them, and often to such an extent as to cause the destruction of the host. When the skin is shed, as the lobster goes from one stage to the next, the whole collection of parasites is shed with the cast-off skin, and the lobster is again clean. The more frequently the skin is cast, the less danger there is from the accumulation of parasites.

3. *What are the general habits of life in the first four stages?*—Some of the habits of the young are described in other chapters, but these observations, with certain additional ones, may be brought together here for convenience.

*Swimming.*—From the time they are hatched until they reach the fourth stage they are essentially swimming animals, and are in no way adapted for living on the botton or in contact with any solid substance. They are constantly in motion; in moments of apparent rest the motion of the swimmerets prevents them from sinking, and for the greater part of the time they are swimming around or executing absurd jerking movements by sudden strokes of the tail. Only slightly do they direct their movements toward particular objects or places, and they are carried by the current in the direction of least resistance. Their constant aimless activity tends to keep them suspended in the water and occasionally brings them into contact with food, but does not protect them from their enemies; indeed, as they have no sense of fear and are very conspicuous in the water, they fall prey to all sorts of animals, fishes, large and small, shrimp, and even to their own brethren.

They swim sometimes at the surface of the water, but again show a tendency to sink to lower depths. The causes of the alternate rising and sinking of these larvæ and of other swimming animals like the jelly-fish, young star-fish, etc., are still obscure. Recent researches have demonstrated for certain species that the direction and intensity of light and the variations in the temperature are among the immediate causes. Undoubtedly the movements of the lobster-fry are affected by the light and perhaps also

by the temperature, but the nature and extent of these disturbances are yet to be learned.

From the practical point of view a great deal more depends upon the understanding of their habits and the effect of temperature and light upon them than would at first appear. Indeed, one of the most serious difficulties, if not the most serious one, in the rearing of the young is that of adapting the apparatus to the peculiarities of the swimming-habit. This subject will be taken up again in the account of our experiments (p. 70).

What has been said above applies to the first, second, and third stages of the young lobster. When the skin has been shed the third time and the lobsters have entered the fourth stage, there is immediately an almost miraculous change in their habits. In many respects the difference between the fry in the third and fourth stages is far greater than between animals belonging to different orders, and the change may be compared to the metamorphosis of flying insects from their larval to their winged condition. In the lobsters, however, the direction of the change is the reverse of that in the insects. The former at once become adapted to life on the bottom. They tend to quit their swimming-habits, except for purpose of changing their position, capturing prey, etc. They crawl over the bottom, hide under shells and sea-weed and, if these objects can not be found, they even burrow in the sand.

Not the least remarkable of the altered characteristics of the fourth stage is their mental attitude. Upon entering this stage they are born again, they know good and evil; for the first time the sense of fear is evident, and they retreat from danger; there is, in short, a purpose and direction in their activities which was not apparent in the three earlier stages.

It should not be inferred that they lose the power of swimming—this is not lost for months—but the swimming is now for the purpose of going from place to place, or for retreating from danger, not merely to keep them afloat.

A brief statement of one experiment will illustrate the suddenness of this change of habit. Three hundred specimens recently

moulted into this stage were put into a car which had gravel and stones in the bottom. Within ten minutes not a single specimen was in sight.

The suddenness and completeness of this change so conducive to the safety of the lobsters gives much practical and economic interest to the problems of rearing the young through the critical period. The advantage of rearing trout to the fingerling stage before liberating them has been amply demonstrated, but the value of protecting the lobsters through their early stages (from 12 to 20 days) is even greater.

*Moulting, or Shedding.*—The habit of shedding the skin begins when the lobsters are two or three days old and continues throughout life. The intervals between successive moults grow longer as the age increases. It has already been stated that the first three moults occur in about twelve days, on the average, at Wickford. There is much variation, according to different conditions. Late in life the periods are longer, and the adult may not shed more than once a year. In the first moults, as in the succeeding ones, the process is the same, the old skin being split across the back, between the thorax and the abdomen, and the body worked out through this opening, leaving the cast skin otherwise intact.

The actual process of moulting usually occupies only a few minutes, but not infrequently something goes wrong and the struggle is quite prolonged. Often the lobster dies in the process, and the period of moulting is at best a very precarious one in the life of the lobster, whether in the young stages or in the later ones.

*Feeding-habits.*—No animals, with the exception of typhoid convalescents, are more voracious than newly-hatched lobsters. They feed normally upon all sorts of minute organisms, copepods, diatoms, etc., and will readily eat some kinds of flesh, if chopped into fine pieces and kept suspended in the water where the fry come in contact with it. Apparently they do not distinguish food sufficiently well to go to it from any considerable distance, but take

what they come in contact with; and as they are continuously moving about in an ocean full of organisms, they must but rarely want for food.

## Lobster-Culture.

The experiments in rearing the fry through the critical period have demonstrated that the chief difficulties to be contended with are, first, that of supplying proper food; and, second, that of furnishing adequate protection.

4. *What is the best method of supplying food?*—When a large number of fry are kept in an enclosure, the natural food supply, consisting of other organisms, is of course not sufficient in quantity and other food must be introduced. It is possible sometimes to collect little crustaceans (copepods) in abundance and put these into the enclosure with the fry. However, this method has practical disadvantages, since it is frequently difficult or impossible to collect the small organisms in sufficient number, and even when they have been collected and placed in the cars with the lobsters, they will often escape through the netting or gather in one place whither they are attracted by the light. Some method must be resorted to, which will provide the food in greater quantities and with greater certainty. The fry decidedly prefer an animal to a vegetable diet, and, while shrimp can be fed satisfactorily on bread, the lobsters will not eat it.

In providing an animal food it is necessary to select tissues which can easily be shredded or crumbled into small pieces. One of the best foods in this particular is lobster liver, which is readily shaken into minute short filaments. At the present price of lobsters this diet is rather too luxurious to be used on a large scale, and furthermore the experiments seem to indicate that it does not agree with the fry. Shredded fresh fish is fairly good, and very satisfactory in the later stages. The best food so far discovered is the soft parts of clams. The bodies of the clam are cut out and chopped into fine pieces in a chopping-tray and then thrown into the water. Even the larger pieces of the soft tissue can be torn

apart by the smallest fry. This diet also seems the best suited to the lobster's digestion.

Two precautions should be observed in feeding with this or with any other food except living organisms: first, the food particles must be kept suspended by stirring or by mixing with air so that the lobster can readily find them; and, second, the food remaining over must not be allowed to decay. In the experiments of last summer the fry were fed twice a day.

There is one habit of the fry which makes the question of ample food supply especially important, their atrocious cannibalism. From the moment they are hatched, throughout the early stages of life, their affection for one another takes this disgusting form. The only way to prevent them from destroying one another is to give them an abundance of food, and in such a manner that they will take it in preference to other lobster-fry.

5. *What is the best means of protecting the fry during the first three stages?*—There are two main difficulties in the way of providing a suitable enclosure for the fry which will allow them sufficient freedom, and which will at the same time confine them and protect them from enemies. The fact that the young fry swim aimlessly about and are carried hither and thither by the currents constitutes the first difficulty, for when they are placed in an enclosure provided with a screen which will allow a free circulation of water from the outside, but shuts out the enemies, the fry are carried against the screen and die. Such an experiment was described in the report of last year by Prof. Bumpus. The second difficulty is quite as serious and is due to the fact that at certain times the fry have a tendency to leave the surface and sink to the lower depths, as described on page 65. Many of the earlier experiments failed on account of this characteristic of the fry.

The endeavor was made to rear them in large cars, such as were used at Wood's Hole for holding cod, but provided, of course, with screen sides. This and other similar experiments failed, because the lobsters would be carried against one side by the tide and there gradually sink to the bottom, where they became foul

with accumulated silt and unused food, and were apt to meet with death in fighting one another. Cars were constructed with screen bottoms, which prevent to a large extent the accumulation of sediment, but even in these there was always some place in the bottom of the car where the lobsters and any waste matter would collect through the action of currents, and here the lobsters would eventually die from suffocation or from fighting.

The apparatus which promised the best results was tried by Prof. Bumpus in the summer of 1899. This consisted of large square bags made of scrim, fastened to a float, and weighted at the lower corners. The action of the tides and winds tended to keep the sides and bottom of the bag in constant undulating motion, and thus prevented the fry from lying long in one place, if they were inclined to sink.

This was the method which was almost exclusively used at Wickford during the past summer, although a few unsuccessful experiments were made with cars.

Many of the experiments were made to ascertain the best pattern for bags and the best method of weighting them. Several large bags 15 x 15 x 3 feet deep were tried, some smaller ones 8 x 9 x 3 feet deep, but the pattern used for the most part were about 4 x 6 x 3 feet deep. Various devices for keeping the bottom under water were used—lead weights on the bottom on the corners, and on the sides heavy weights and light weights, while some bags were tied down with strings from the corners.

By careful observation of these experiments a considerable advance was made in the knowledge of the danger to be avoided and the means of overcoming some of the difficulties.

The large bags were failures, the next in size were better, but the most successful were the bags of the smallest size.

Under favorable conditions, *i. e.*, with a moderate wind and tide, the small bags lightly weighted are quite satisfactory. The bottoms and sides are moved in rhythmic motion, and the fry keep from gathering together at any one spot. But, when the wind or tide increases, the bags are carried to one side and held

in one position, even if not blown out of the water, and the conditions are very trying to the young fry. If heavier weights are put on, to hold the bags in place, pockets are formed where the weights are attached, and into these pockets the fry sink, together with particles of food, etc., and a high rate of mortality ensues. The most serious condition is a dead calm, for this is almost sure to allow the bottom of the bags to sag into pockets even when light weights are used, and thus sooner or later the young sink into these pockets. Weights fastened on the sides instead of on the bottom obviate this difficulty to some extent, but even then pockets will at some time be formed.

After making numerous experiments and watching the results for about five weeks, we gradually came to the conclusion that the secret of success in rearing the young lobsters was to keep the water in continuous motion. This accomplishes two things: it prevents the fry from settling into pockets to smother or devour one another, and it keeps food in suspension so that the fry can obtain it.

To prove the correctness of this conclusion with the material and apparatus at hand, it was decided, on July 6, to experiment with lobsters which were at that time in small bags. Accordingly the force at the laboratory was divided into watches, and the water in the bags was thenceforth stirred with an oar continuously until July 12. The result was ample proof that the conclusion was correct. There were two lots of lobsters which received this treatment, namely, experiments 9 and 10 (tables on page 78). Neither of these lots was considered to be as promising as the average. However, from No. 9 there were obtained 748 lobsters in the first stage. This is a larger number than were obtained in any other experiment, either at Wickford, Wood's Hole, or in any other station where lobster-culture has been tried, so far as I am aware. From lot No. 10, 319 were obtained in the fourth stage; but as one of the bags was old and had a hole in it, the figures fail to give a correct idea of the results of the experiment. One of the most encouraging results of this method was the clean and

healthy appearance of the fry in all stages. The continual stirring prevented the accumulation of parasites found on the body of nearly all of the specimens in the other lots.

It is intended during the next season to follow up this experiment with others, working upon the same theory, namely, that the water should be constantly stirred. To do this it will be necessary to invent a mechanical device which will take the place of the oar, and designs for such an apparatus are now being made.

The total number of fry reared to the fourth stage during the season at Wickford was 3,425, and the number for each lot, together with the more important data, is given in the table on page 78.

In comparison with the results of the many attempts to rear lobsters in various places during this and previous years, the results at Wickford were eminently successful.

## Observations on the Later Stages.

While the main problem for the past summer was to learn the habits and discover means for rearing the lobster up to the fourth moult, it was impossible to resist the temptation of trying some preliminary experiments on the later stages. Accordingly several cars were constructed with wire gauze sides and having heavy plank boxes for bottoms. Gravel, stones and some sea-weed were placed in the boxes, in order to imitate as closely as might be the natural environment. Lobsters from various lots were put into these cars, some as soon as they reached the fourth stage, and others later.

Without going into a detailed record of these experiments, we may state the general results as follows:

The lobsters seemed to find in these boxes a very natural environment, and immediately took shelter under stones and shells or else burrowed. Often an excavation of considerable size was made by carrying out pieces of gravel and depositing them at a short distance from the hole. These excavations in many instances

reached three or four inches in depth. The habit of burrowing was also noted even in fourth stage lobsters, and was continued throughout the later stages. When food (chopped clams or fish) was placed in the cars, the lobsters came stealthily out of their hiding-places, and having grabbed a morsel, retreated backward into their holes, guarding the entrance with their big claws.

They appeared to avoid travelling about in the day-time, but at night and just at dawn could be seen quietly moving along on the ground. Occasionally, for some unaccountable reason, some of the specimens, even when more than an inch long, would take to swimming rapidly around the car, but for the greater part of the time they appeared to be contented with their surroundings; so much so, indeed, that when a storm on September 12 broke loose the screens on the sides, and nothing prevented their escape, a large number appeared to prefer remaining where they were.

One important point which has been demonstrated is that the lobster, after reaching the fourth stage, can easily be kept in an enclosure, and will thrive with much less care than is required by those of the early stages. As soon as they reach the fourth stage they should be transferred to a car or enclosure provided with a sandy or gravelly bottom, for when they are kept in other cars they do not thrive so well and are apt to become foul with various parasitic growths. I have seen specimens in the fourth stage that were covered with green algæ half an inch long, so that by a casual examination one could not have told that they were lobsters.

A considerable number of these specimens were kept throughout the fall and winter, and on December 22 half a dozen were taken out and subsequently carried to Washington alive and placed in the aquarium of the U. S. Fish Commission.

Some interesting facts were learned in regard to the rate of growth. The most rapid growth took place between July and the middle of September. This is natural because of the low temperature in the later fall, and more especially because they were seldom fed after the middle of September. The size of some of

the lobsters on September 15 is given in the following table. The measurements are from the tip of the "beak" to the end of the tail, and are given in millimeters. (1mm. = 1-25 inch.)

| *Set 1.* Hatched May 31. Placed in car July 17. 7th and 8th stages. | *Set 3.* Hatched June 10. Placed in car July 16. | *Set 8.* Hatched June 26 or 27. Placed in car July —. |
|---|---|---|
| 38 | 40 | 23* |
| 33 | 32 | 31 |
| 26 | 37 | 35 |
| 35 | 33 | 37 |
| 33 | 38 | 46 |
| 33 | 32 | 36 |
| 44 | 38 | 34 |
| 30 | 35 | 34 |
| 31 | 45 | 40 |
| 38 | 22* | 25 |
| 39 | 40 | 31 |
| 37 | 25 | 35 |
| 30 | 35 | 41 |
| 36 | 22* | 32 |
| 44 | 30 | 31 |
| 30 | 42 | 29 |
| | 40 | 42* |
| Average, 34.81 mm. | 30 | 21 |
| | 30 | 27 |
| | 27 | 27 |
| | 27 | 32 |
| | 30 | 30 |
| | 32* | 37 |
| | 32 | 26 |
| | 21* | 30 |
| | | 33 |
| | Average, 32.6 mm. | 26 |
| | | 25 |
| | | 27 |
| | | 24* |
| | | 20* |
| | | Average, 31.1 mm. |

*Sets 9 and 10.*

Hatched —.
Put in car —.

| | |
|---|---|
| 25* | 24* |
| 40 | 35 |
| 26 | 40 |
| 32 | 26 |
| 33 | 29 |
| 25 | 32 |
| 27 | 25* |
| 40 | 25 |
| 30 | 24* |
| 40 | 20* |
| 38 | 26* |
| 22* | 27 |
| 43 | 26 |
| 33 | 26 |
| 27 | 21* |
| 22 | 22* |
| 44 | 26* |
| 30 | 27 |
| 34 | 24* |
| | 19* |

Average, 29.3 mm.

*Odd sets.*

Hatched —.
Put in car —.

| | |
|---|---|
| 28 | 23 |
| 29 | 30 |
| 37 | 26 |
| 38 | 37 |
| 32 | 37 |
| 25 | 29 |
| 27 | 23 |
| 20* | 31 |
| 34 | 42 |
| 35 | 23 |
| 37 | 34 |
| 38 | 52 |
| 35 | 26 |
| 34 | 36 |
| 37 | 37 |
| 39 | 28 |
| 28 | 22 |
| 30 | 24* |
| | 25* |
| | 24* |

Average, 31.2 mm.

I believe that the growth indicated in these experiments represents fairly well the growth under natural conditions. The cars were of good size, and many species of marine animals and plants thrived on the inside. The lobsters were fed nearly every day.

One of the noticeable features, as shown in the measurements, is the great variation in the rate of growth among the specimens in each of the cars. The age of all the specimens in any one car was the same, but after three months the difference in size was so great that some specimens were not longer than the claws of others. There were in all the cars, except the first (set 1) a number of specimens which retained the two white spots on the back of the

The (*) in the tables denotes that this specimen has the white spots on the first ring of the abdomen, a character of the fifth and sixth stages.

first ring of the tail. This is a characteristic of the fifth and sixth stages, possibly the seventh stage also, and it is quite certain that some of the specimens had shed their skin twice as many times as others of the same age. This variation is shown in two lobsters taken out of the cars on October 17th. (See figure 9.)

This marked variation in the rate of growth is the same phenomenon which has been repeatedly demonstrated in the growth of star-fishes and clams, and makes it impossible to say that a specimen will reach a certain size in a given length of time. In the case of the star-fish and clam the variation has been shown to depend on the food supply, and it is probable that the same is true of the lobster. Although, apparently, the conditions were the same for all the lobsters in a certain car, there are many possibilities of different conditions. The lobsters have a strong individuality, and the activities of different individuals vary to such an extent that it is not strange that some are more successful in obtaining food than others. If, by the same good fortune, a certain lobster obtained an advantage at first, this advantage would increase as time went on, since in lobster society the stronger individuals constantly menace the weaker ones.

These peculiarities make themselves evident at once when a number of lobsters are placed under observation in a small space. I recall one instance in which a certain lobster took for his headquarters the cork which plugged the hole in the bottom of the aquarium. For nearly a week (and until he was killed in a fight) he kept a lookout from the top of this cork or hid in its shadow, occasionally making excursions about the aquarium, but always returning again to the same spot.

In order to keep some of the specimens over winter, they were placed in a car which was covered and sunk in the channel. They were alive on December 22, and it is hoped that some of the specimens can be carried over to the next season.

The following tables present in a condensed form the main results of the experiments in lobster culture at Wickford.

The first four photographs represent the first four stages in the

life of the lobster, from drawings by Prof. Herrick. They are many times life-size.

The next six figures (5–10) are from life-size photographs of lobsters reared at Wickford.

February 22, 1901.

| Experiment number. | Date of hatching. | Date received. | Number received.* | Apparatus used. | Food. | Condition when received. |
|---|---|---|---|---|---|---|
| 1 | May 31 | June 1 | 2,000 | Three small bags; heavy weights<br>Small car | Lobster liver, clams | Good |
| 2 | June 8 | June 9 | 2,000 | Two bags (small) in float | Clams | Good |
| 3 | June 10 | June 11 | 30,000? | Three bags (new) | Clams | Fair |
| 4 | ........ | June 14 | 50,000? | Large bag | Clams | Many dead |
| 5 | ........ | June 18 | 70,000? | Small bag, and on June 19 large bag | Clams | Very poor. |
| 6 | June 22 | June 22 | 5,000 | Large bag | Lobster liver, clams | "Gilt edge" |
| 7 | ........ | June 25 | 20,000? | Two small bags and one large one | Clams | Good |
| 8 | ........ | June 27 | 15,000 | Two small bags, and larger bag in pool | Clams | ........ |
| 9 | ........ | July 2 | ........ | ........ | ........ | ........ |
| 10 | ........ | July 5 | ........ | Three small bags and large car with wire-mesh bottom | Clams | Poor |
| 11 | ........ | July 11 | ........ | Two small bags, and one small bag (very deep) | Clams | Very poor† |

* Estimate. † Mostly dead.

| First of second stage appeared. | Majority in second stage appeared. | First in third stage appeared. | Majority in third stage appeared. | First in fourth stage appeared. | Majority in fourth stage appeared. | Average time from hatching to fourth stage. | Average temperature between hatching and fourth stage. | Total number of fourth stage. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| ........ | June 6 | June 9 | ........ | June 13 | June 16 | 16 days | 65° | 320 | Calm on June 3. Bags changed at third stage; killed many. |
| ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | All died. |
| ........ | June14? | ........ | June19? | June 21 | June 23 | 15 days | 66° | 212 | On June 21, 230 in third and 77 in fourth stage. |
| ........ | ........ | ........ | June19? | June 22 | June 24 | 13 days | 68° | 598 | Many dead when received. Last of third stage moulted June 26—16 days. |
| ........ | June 19 | June 21 (10pr.ct.) | ........ | June 26 (25pr.ct.) | June 27 | 13 days | 68° | 186 | Brought from Wood's Hole packed in ice. |
| June 21 | ........ | ........ | June 24 (fresh bag) | June 27 | July 2 | 13 days | 69° | 522 | On June 24 big bag was very foul, and 1,420 of second and third stages were put in fresh small bag. These yielded 339 at fourth stage. |
| ........ | ... .... | ........ | ........ | July 2 | ........ | 10 days | 70° | 2 | On June 23 estimated 1,000 dead from stagnation. On July 2 nearly all dead. |
| ........ | June 29 | ........ | July 4 | July 5 | July 8 | 12 days | 72° | 119 | Those put in big bag nearly all died. Only 2 reached fourth stage. |
| ........ | ........ | ........ | July 4 | ........ | July 9 | 12 days | 72° | 350 | Injured by violent wind, June 28. |
| ........ | ........ | ........ | ........ | July 9 | July 12 | 10 days | 72° | 748 | On July 11—9 days—there were 165 at fourth stage. Stirred constantly from July 6 to July 12. First of fourth stage in 7 days. |
| ....... | ........ | ........ | July 10 (very clean) | July 11 | July 14 | 9 days | 72° | 319 | All those in car died from crowding together. Bags stirred continuously. Hole in one bag let many out. |
| ........ | ........ | ........ | July 16 | July 4 | July 23 | 11 days | 73° | 49 | This set was very poor, and received little care. |

Average time from hatching to fourth stage = 12+ days.

Total number of fourth stage = 3,425.

PLATE I.

FIG. 1. Magnified drawing of lobster in the first stage, *i. e.*, just hatched from the egg. Compare with fig. 5. (After Herrick.)

FIG. 2. Magnified drawing of lobster in second stage (having moulted once). (After Herrick.)

Plate I.

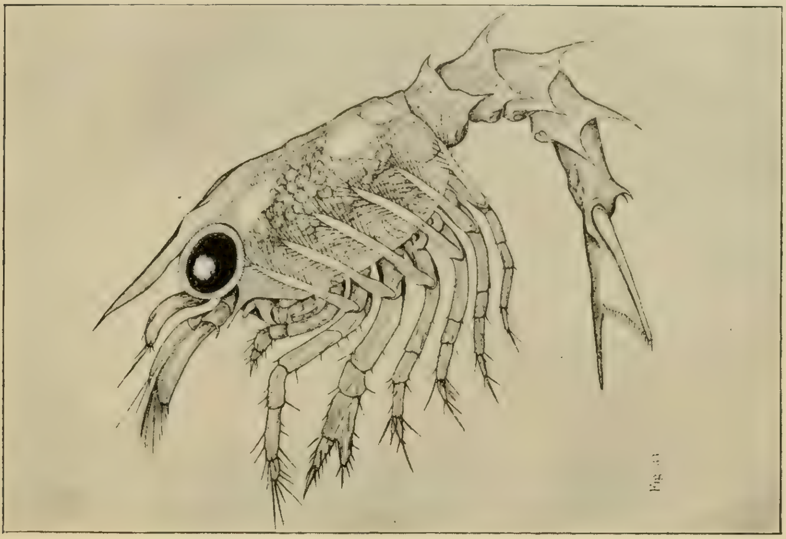

Fig. 1.

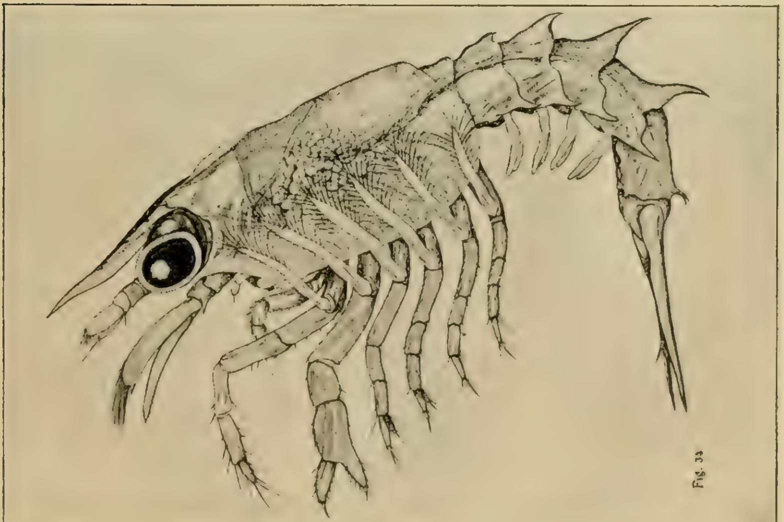


Fig. 2.

PLATE II.

FIG. 3. Magnified drawing of lobster in third stage. (After Herrick.)

FIG. 4. Magnified drawing of lobster in fourth stage. (After Herrick.)

PLATE II.

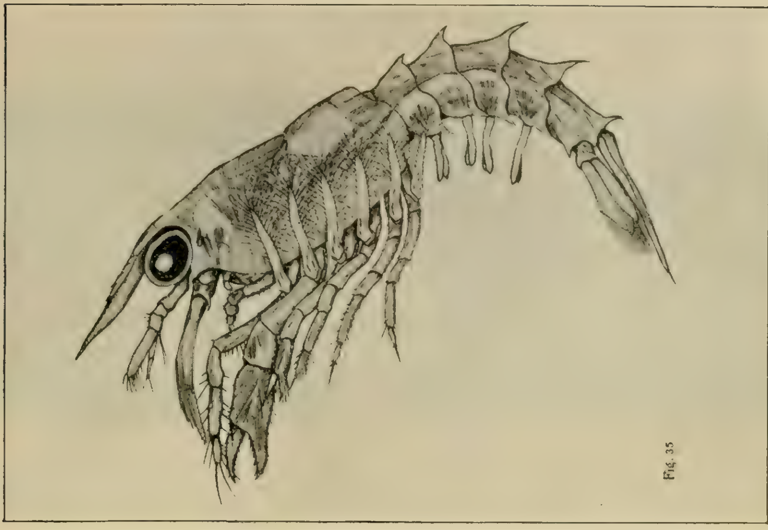


FIG. 3.

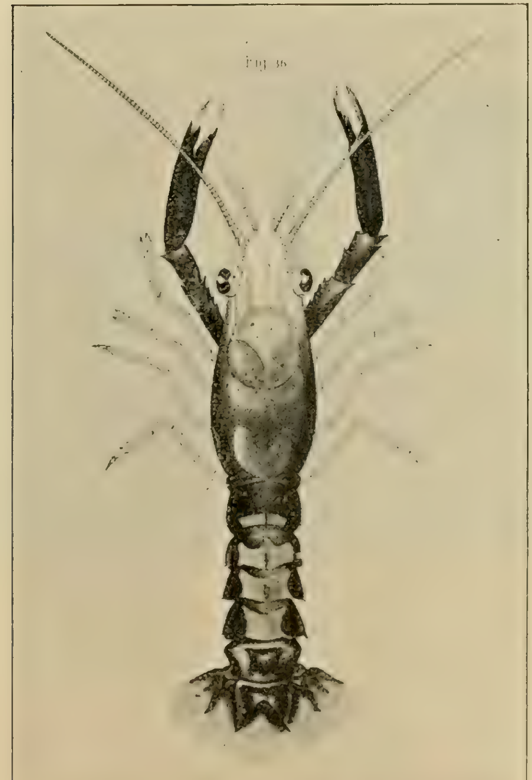


FIG. 4.

PLATE III.

FIG. 5. Life-size photograph of lobsters in first stage.

FIG. 6. Life-size photograph of lobsters in the second stage.

FIG. 7. Life-size photograph of lobsters in the third stage.

FIG. 8. Life-size photograph of lobsters in the fourth stage.

PLATE III.

FIG. 5.

FIG. 6.

FIG. 7.

FIG. 8.

## Plate IV.

Fig. 9. Life-size photograph of two lobsters of the same age—$4\frac{1}{2}$ months—showing variation in size. Reared in car at Wickford June 1 to October 17.

Fig. 10. Life-size photograph of lobster taken from car Dec. 22, and about 6 months old.

Plate IV.

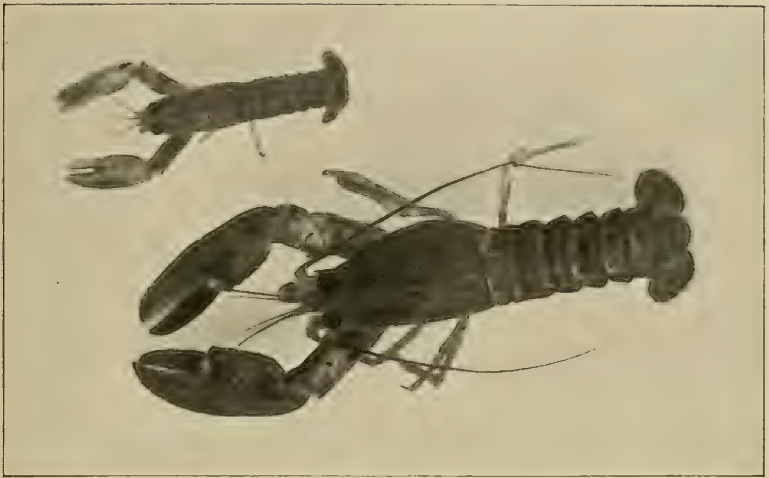

Fig. 9.

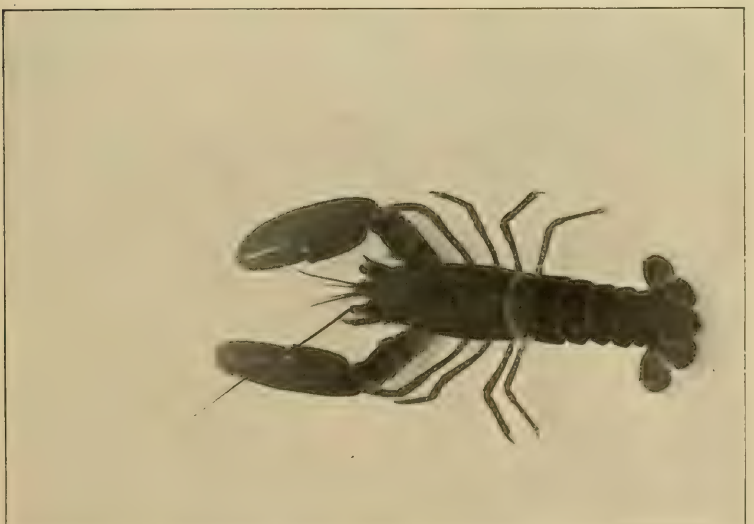

Fig. 10.